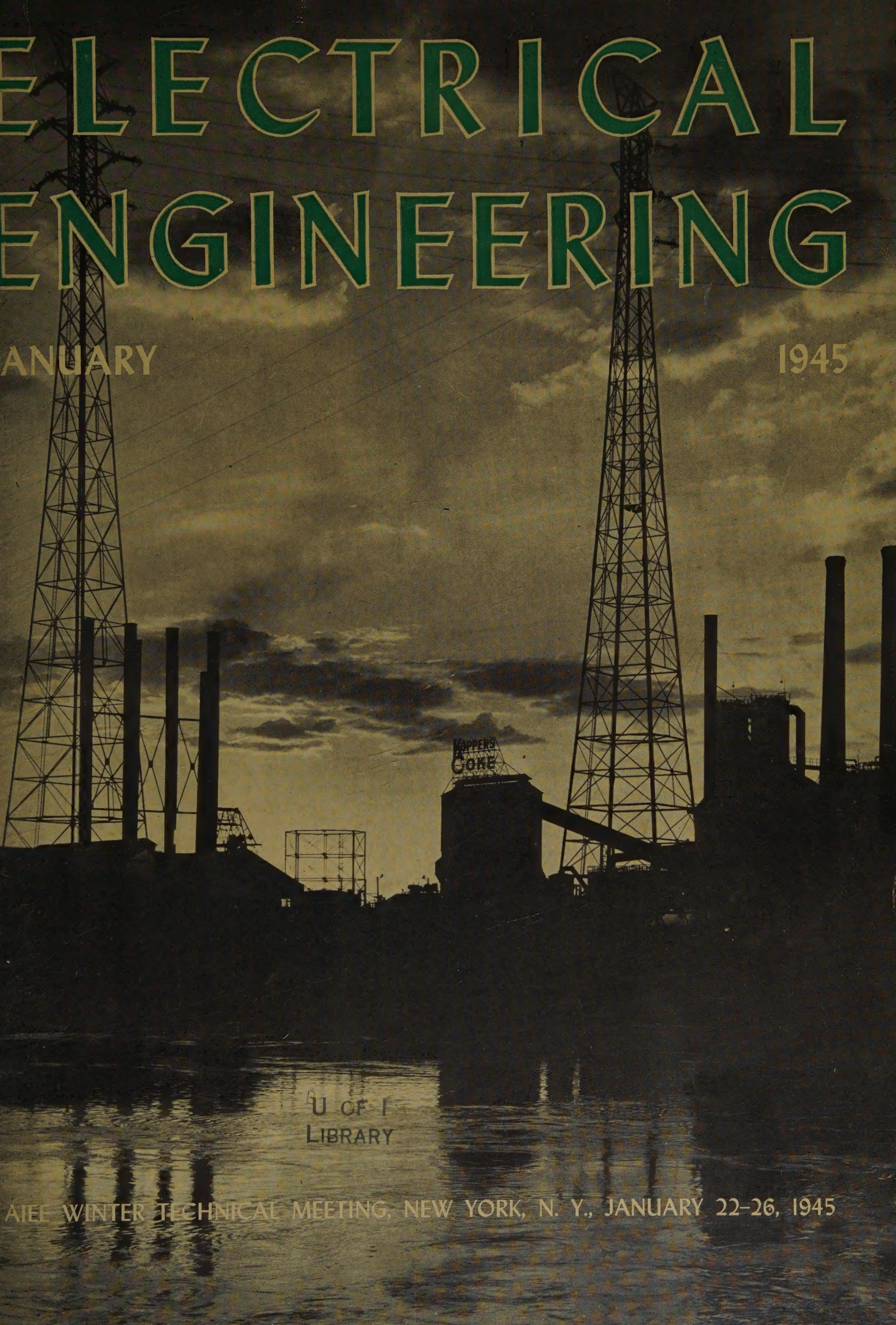
ELECTRICAL ENGINEERING

JANUARY 1945



AIEE WINTER TECHNICAL MEETING, NEW YORK, N. Y., JANUARY 22–26, 1945

ELECTRICAL ENGINEERING

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The Cover: Transmission towers are symbols of electric power, essential to the many industries in and around New York, N. Y., where the AIEE winter technical meeting will be held January 22–26, 1945.

TRANSACTIONS SECTION

(Follows EE page 46; a preprint of pages 1–40 of the 1945 volume)

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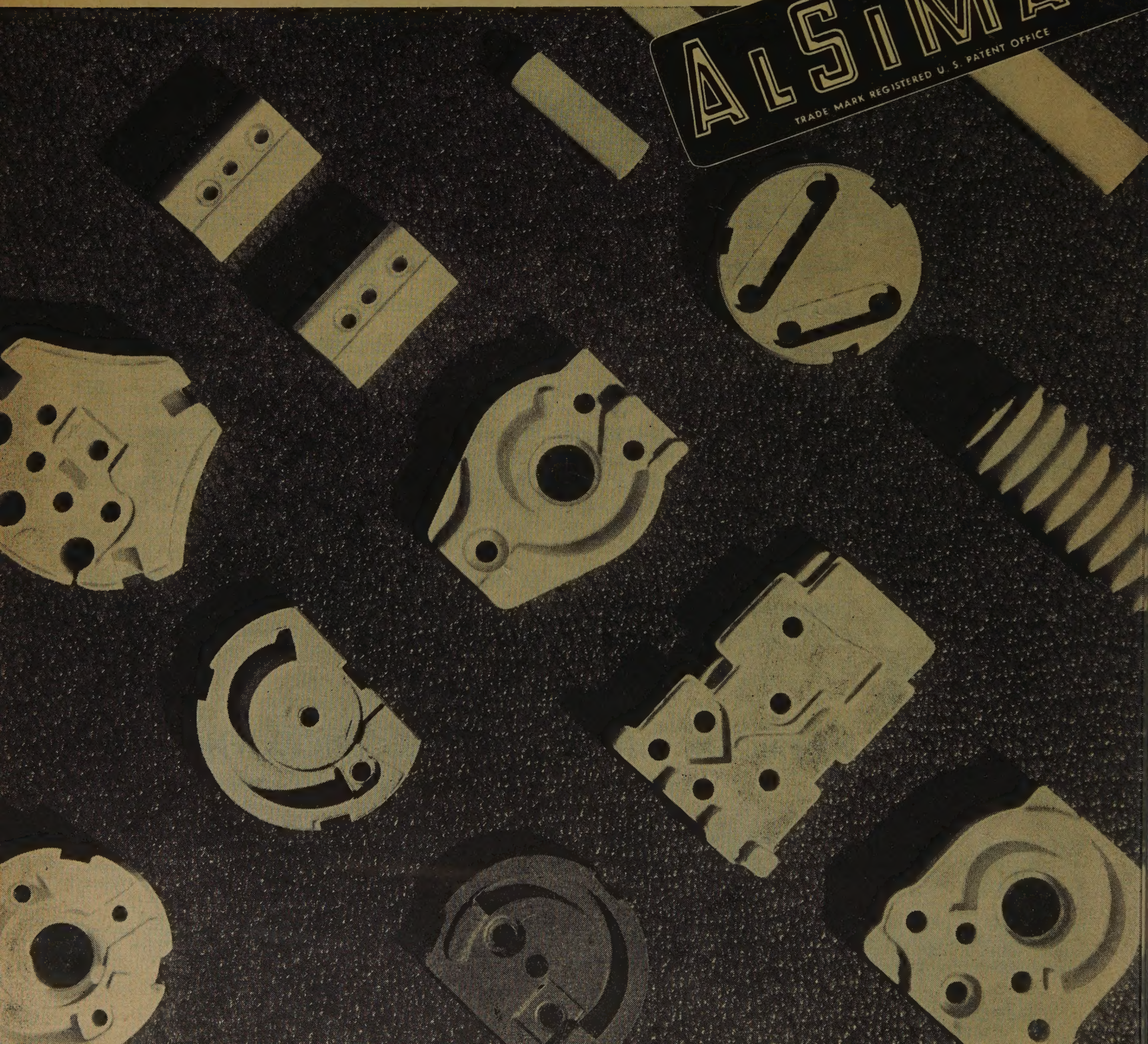

ELECTRICAL ENGINEERING
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Grounding Principles and Practice

I—Fundamental Considerations on Ground Currents

REINHOLD RÜDENBERG
MEMBER AIEE

This article is the first of five based on a series of lectures which was sponsored by the power and industrial group of the AIEE New York Section during the 1943–44 season. The behavior of currents flowing in the earth, as influenced by the resistivity of the soil, frequency of the current, and size and shape of electrodes, is analyzed here.

IN THIS ARTICLE are considered the main scientific problems related to the conduction of electric currents to the earth and through the ground. While the overall performance of an electric system in which one or more points are grounded depends on the behavior of the wire network and the ground, this article is confined to the underground flow of the electric currents, which is not so easily measurable and therefore not so well understood as the behavior of the currents in the overhead network.

The earth is a body of three dimensions and therefore the beautiful simplicity of the linear wires by which electric currents usually are directed is lost. In the earth the currents spread out in the entire space, and it is necessary to follow their paths in order to analyze their performance in the underground.

The earth has been used as a conductor for electric currents since the beginning of engineering. However, after a brief period of preference for sending return currents through the ground, great difficulties and hazards were found from this in all branches of electrical engineering. Nowadays the earth is used mainly for fixing the neutral point of the electric system, and in many instances the inclusion of the earth as part of the circuit cannot be avoided.

RESISTANCE OF THE SOIL

Geological Strata. The electric conductivity of the materials constituting the earth's surface is very low compared with the high conductivity of the metals. Two main constituents of the earth, silicon oxide and aluminum oxide, actually are excellent insulators, and the conductivity of the ground is due in large measure to salts and moisture embedded between these insulators. On the other hand, even a semiconductor may carry a considerable amount of current if only the cross section is large enough, and in this respect the earth, by its great depth, presents no limitations.

Because of the high resistivity, all currents flowing through the ground suffer a considerable voltage drop. Therefore we must break with the popular concept that the potential of the ground is always zero. A substantial electric-field strength, or potential gradient, can develop and this may affect extended regions of the earth's surface. We have to distinguish between two different zones which will be considered in detail, namely, the spaces in proximity to the ground electrodes and the long path between such electrodes.

The ground under the surface of the earth is by no means homogeneous, and this makes a rigorous analysis of the distribution of currents very difficult if not impossible. Figure 1 represents a typical geological cross section of the underground indicating the great heterogeneity of the conducting body through which electric currents may pass. Random changes caused by weather and seasons, by rain, frost, and by other temperature variations, with their influence on the conductivity of the soil, increase the difficulty of analysis. It would not be wise, therefore, to develop here the laborious considerations for a very high degree of accuracy. However, a quantitative analysis of the electric phenomena in the ground is necessary in order to make numerical calculations and to draw definite conclusions if the electric system from time to time shall not experience technical trouble or cause serious accidents.

Variation of Earth Resistivity. The resistivity of the soil depends on many parameters. It depends on the type of soil and therefore varies with distance as well as with depth, as indicated by Figure 1. Further, the resistivity is much smaller below the subsoil water level than above it. In frozen soil, as in the surface layer in winter, it is particularly high. It is important, therefore, for good ground electrodes to avoid the frost limit and to reach the subsoil water plane. Figure 2 shows the variation of resistivity ρ of a certain soil as measured (*a*) versus moisture content, (*b*) versus temperature change, and (*c*) versus added salt in per cent of weight. It is seen by the logarithmic scales used that these three parameters affect the earth resistivity by several powers of ten, thus very large variations may occur.

Attempts have been made to correlate the resistivity with the geological age of the strata. Although older material in general has higher resistivity, many exceptions were found. In the actual strata under the surface, loam, clay, and limestone usually have lower resistivity; sandy and rocky materials have higher resistivity. While for power networks and for radio waves the resistivity near the surface is more important, for telephone interference by action at a distance the resistivity of the deeper layers has greater significance.

SPHERICAL GROUND ELECTRODES

Current Paths and Grounding Resistance. There will be considered first the simpler electrode elements and later some of the more complex combinations used in practice. For quantitative calculations the meter-kilogram-second system will be used which leads directly to the practical electric units.

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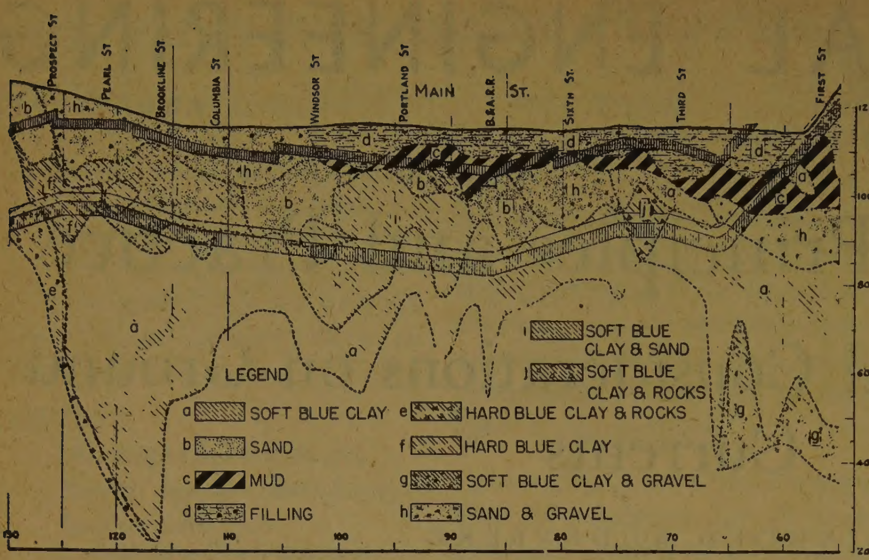


Figure 1. Subsoil strata under Main Street, Cambridge, Mass.

The simplest possible electrode is shown in Figure 3, namely, a sphere in the ground which is symmetrical in all directions. It may be entirely embedded in the ground, or only the lower hemisphere embedded in the half space of ground under the surface plane of the earth, a case which will be considered. If a current I flows through this electrode, spreading out radially in the ground, the current density at distance x from the center of the hemisphere is

$$i=\frac{I}{2\pi x^2} \tag{1}$$

According to Ohm's law such a current produces in the resistivity ρ of the soil an electric-field strength

$$e=\rho i=\frac{\rho I}{2\pi x^2} \tag{2}$$

The voltage, as line integral of the field strength from the surface of the conducting sphere of radius B to the distance x, is therefore

$$E=\int_B^x e dx=\frac{\rho I}{2\pi}\int_B^x \frac{dx}{x^2}=\frac{\rho I}{2\pi}\left[\frac{1}{B}-\frac{1}{x}\right] \tag{3}$$

Current density, field strength, and voltage, in their dependence on distance, are represented graphically near the top of Figure 3.

The total voltage between the spherical electrode and a far distant point with $x=\infty$ is, according to equation 3,

$$E=\frac{\rho I}{2\pi B} \tag{4}$$

and therefore the resistance experienced by the streamlines of current diverging from the hemisphere is

$$R=\frac{E}{I}=\frac{\rho}{2\pi B} \tag{5}$$

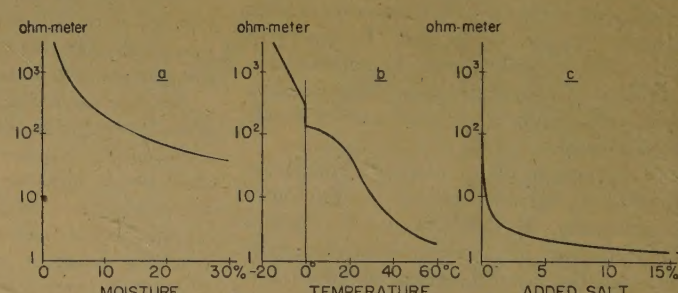
Any additional resistance due to incomplete contact of the electrode and the ground occurs only rarely in practice.

If we consider, for a numerical example, a hemispherical electrode of radius $B=1$ meter embedded at the surface of the earth of resistivity $\rho=10^2$ ohm-meter, the ground resistance of this electrode will be

$$R=\frac{10^2 \text{ ohm-m}}{2\pi\cdot 1\text{m}}=16 \text{ ohms}$$

As the curves in Figure 3 show, this resistance is distributed over the entire half space; however, the major part of it is concentrated in proximity to the electrode.

Figure 2. Resistivity of the earth depending on moisture, temperature, and salt contents



If two such electrodes are used through which the current enters and leaves the ground, the streamlines of the current develop as superposition of two hemispherical current distributions. This is shown in Figure 4a under the assumption that the resistivity of the soil is uniform in space. If a voltage of 110 volts is impressed between the electrodes, one having a diameter of 10 meters and the other of 1 meter, and separated by a distance of 1,000 meters, the streamlines and equipotential lines develop as shown in Figure 4a, and concentrate mainly around the smaller electrode.

If, on the other hand, a more highly conducting layer should exist at the surface of the earth, for example after a heavy rain, then the streamlines do not develop in depth but remain near the surface. Their shape within this layer and the distribution of potential are shown in Figure 4b for electrodes of the same dimensions and distance apart as before. Here the voltage does not concentrate so heavily near the electrodes but spreads out over larger areas of the surface.

Field Strength on Surface. If a man or an animal is walking through such a surface field of electric potential, for example in the neighborhood of a faulty transmission tower, as shown in Figure 5, the body diverts some current from the earth and may suffer damage from the potential gradient. The tower footing carrying a current I to the ground can be represented for the present purposes by an equivalent hemisphere of radius B, as shown by the dotted line in Figure 5. The field strength on the surface of the ground is then given by equation 2 and increases toward the tower to a maximum value at distance B

$$e_B=\frac{\rho I}{2\pi B^2} \tag{6}$$

With the figures of the former example and with a tower current to ground $I=100$ amperes, the maximum field strength at the surface is

$$e=\frac{10^2 \text{ ohm-m}\cdot 100 \text{ amp}}{2\pi\cdot(1\text{m})^2}=1{,}600 \text{ volts per meter}$$

a remarkably high value.

This field strength produces a current in any living creature stepping over the surface. The maximum possible current develops if the internal body resistance is small compared with the foot resistance on the ground, which is

$$r=\frac{\rho}{2\pi b} \tag{7}$$

if b signifies the equivalent radius of the creature's foot. For a man's foot this has been measured in an electrolytic trough as $b=7$ centimeters on the average. Since the voltage drop by the body current through the resistance $2r$ due to both feet is given by the voltage taken over the step length s

$$2ri_s=es \tag{8}$$

and therefore the maximum body current becomes

$$i_s=\frac{es}{2r}=\frac{\pi bes}{\rho}=\frac{sb}{2x^2}I \tag{9}$$

if expressed in terms of the tower current I.

With the numerical values already used, there is obtained for a man taking a step one meter long at a distance of three meters from the center of the tower, a body current

$$i_s=\frac{1\text{m}\cdot 0.07\text{m}\cdot 100\text{ amp}}{2\cdot(3\text{m})^2}=0.39\text{ ampere}$$

and this maximum current is certainly deadly.

Measurements by Probes. Measurements of ground resistance require some considera-

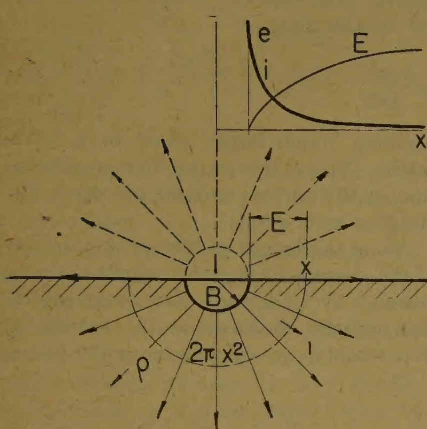


Figure 3. Radial flow of current from spherical electrode to ground

tion. Care should be taken that probes or auxiliary electrodes, as in Figure 6, are sufficiently far removed from the spreading-out zone of the main current, if the probes are to measure the entire resistance experienced by the current. The voltage E will be independent of the distance x between the main and auxiliary electrodes only if x is much greater than both b and B.

By application of equation 3 to both systems of current distribution of Figure 6 around the hemispheres of radii B and b, superposition gives the voltage between the two electrodes. Thus the total resistance is

$$\frac{E}{I}=\frac{\rho}{2\pi}\left[\frac{1}{B}+\frac{1}{b}-\frac{2}{x}\right] \tag{10}$$

which is smaller than the sum of the resistances R and r proper of the two electrodes. By equation 10, ρ can be determined from the measured quotient of voltage and current if the dimensions are known and if ρ is constant over the ground. If this latter cannot be assumed, the resistivity around the smaller electrode nevertheless can be measured if its radius b is made so small that it is much less than both B and x, so that not only the last term but also the first term in the bracket of equation 10 becomes negligible. This gives the resistivity

$$\rho=2\pi b\,\frac{E}{I} \tag{11}$$

as determined only by the quotient of voltage and current and the linear dimension b of the probe. In this way numerous measurements have been performed showing that there are very great differences in the resistivity of the natural soil.

If no specific measurements for a definite spot of ground are made, the figures of Table I may be used as average resistivity over the underground.

Two Parallel Ground Electrodes. If two electrodes are arranged mutually within their spaces of high field strength, as in Figure 7, they experience mutual influence. For each of the spheres in Figure 7 the voltage from the sphere of radius b through distance y is, by equation 3,

$$E=\frac{\rho I}{4\pi}\left[\frac{1}{b}-\frac{1}{y}\right]=V_b-V \tag{12}$$

Since the voltage is determined by the difference in the bracket, which depends only on distances, the voltage can be expressed by the difference of two potentials, as on the right-hand side of equation 12. The potential V of a spherical source of current in space is therefore

$$V=\frac{\rho I}{4\pi y} \tag{13}$$

and such potentials always superpose if more than one source is present.

In the center plane between the two spheres of Figure 7, the potential is therefore

$$V_x=2\,\frac{\rho I}{4\pi y} \tag{14}$$

if both spheres carry equal currents I to the ground. On the other hand, at the surface of either sphere the self-potential is determined by the radius b, the mutual potential by the average distance $2z$ between the centers of the spheres. The total potential is therefore

$$V=E=\frac{\rho}{4\pi}\left(\frac{I}{b}+\frac{I}{2z}\right)=\frac{\rho I}{4\pi b}\left(1+\frac{b}{2z}\right) \tag{15}$$

Hence the resistance of two spheres in parallel in the ground, carrying together the current $2I$, is

$$R=\frac{E}{2I}=\frac{\rho}{4\pi b}\cdot\frac{1}{2}\left(1+\frac{b}{2z}\right) \tag{16}$$

The first quotient, by comparison with equation 5, gives the ground resistance of one sphere. The last factor for far-distant electrodes with $z=\infty$ becomes $^1/_2$; but for close electrodes, for example, with $z=b$ becomes $^1/_2(1+^1/_2)=^3/_4$. Thus distant spheres are mutually independent in their resistances and their parallel resistance can be computed according to ordinary rules. Close electrodes, however, experience an increase of their ground resistance by mutual interference.

Table I. Average Resistivity of the Ground

Type of Ground	Resistivity ρ, Ohm-Meters
Wet organic soil	10
Moist soil	10^2
Dry soil	10^3
Bed rock	10^4

Depth Electrode. Figure 8 shows a spherical electrode buried in depth. Considering the arrangement of Figure 8 as half that of Figure 7, we obtain the resistance of such a depth electrode as twice that of equation 16, namely,

$$R=\frac{E}{I}=\frac{\rho}{4\pi b}\left(1+\frac{b}{2z}\right) \tag{17}$$

Near the surface, for example at $z=b/2$, we have $\left(1+\frac{b}{2b/2}\right)=2$, and the resistance becomes the same as with equation 5. Under the surface the resistance decreases and in greater depth the correction term $b/2z$ vanishes, thus cutting the resistance in half.

With a depth electrode the space of high current concentration is not accessible to creatures, thus the danger of stepping near the electrode decreases. At any point of the surface, as seen by Figure 8,

$$\frac{x}{y}=\sin\alpha=\frac{dy}{dx} \tag{18}$$

where x is the distance from the axis of the depth electrode and α the corresponding central angle. Thus the field strength at the surface is

$$e=\frac{dV_x}{dx}=\frac{dV_x}{dy}\sin\alpha \tag{19}$$

Substituting the potential V_x from equation 14, we obtain the field strength at the surface

$$e=\frac{\rho I}{2\pi}\,\frac{d(1/y)}{dy}\,\sin\,\alpha=\frac{\rho I}{2\pi}\,\frac{\sin\alpha}{y^2} \tag{20}$$

Now, for α near 90 degrees, $\sin\alpha/y^2=1/x^2$; while for small values of α, $\sin\alpha/y^2=x/z^3$. Therefore the field strength at large distances decreases exactly like that around a hemisphere, while vertically over the depth electrode the field strength becomes zero and rises linearly for small values of x. At an angle determined by $\tan\alpha=1/\sqrt{2}$, the field strength is a maximum, namely,

$$e=\frac{\rho I}{3\sqrt{3}\pi z^2} \tag{21}$$

The ratio of this value to the maximum value of equation 6 for a surface electrode is

$$\frac{2}{3\sqrt{3}}\left(\frac{b}{z}\right)^2=0.39\left(\frac{b}{z}\right)^2 \tag{22}$$

which shows that a depth electrode, for sufficiently large depth z, minimizes the danger for stepping creatures.

ROD AND WIRE ELECTRODES

Driven Rod at Earth Surface. Spherical or hemispherical electrodes are not con-

venient for actual use. In practice rod or wire electrodes, having a relatively small cross section compared with the length, are preferred. We may subdivide with good approximation such a rod electrode driven into the ground, as in Figure 9, into a large number n of nearly spherical elements, which over the length l of the rod in the ground have a mutual distance

$$dl=\frac{l}{n} \tag{23}$$

each feeding a current I/n into the ground. If y is the distance from any element to a point at the surface of the earth and α is the angle from y to the axis of the rod, the small diagram in Figure 9 shows that

$$\sin\alpha=\frac{yd\alpha}{dl} \tag{24}$$

The potential dV of every element is given by equation 13 with current I/n. By substitution of the distance y from equation 24, and use of equation 23, the incremental potential at the surface of the earth becomes

$$dV=\frac{\rho I/n}{4\pi y}=\frac{\rho I}{4\pi n}\frac{n}{l}\frac{d\alpha}{\sin\alpha} \tag{25}$$

If the limiting value of angle α is denoted by β, as shown in Figure 9, the potential in the center plane of a rod of length $2l$, containing $2n$ spheres and thus including the fictitious image above the ground, is given by the integral of dV from $+\beta$ to $-\beta$,

$$V=\frac{\rho I}{4\pi l}\int_{+\beta}^{-\beta}\frac{d\alpha}{\sin\alpha}=\frac{\rho I}{2\pi l}\log_e\left(\cot\frac{\beta}{2}\right) \tag{26}$$

This result would be rigorous if the density of the current emerging from the rod into the earth were uniform over the length, which actually is only a fair approximation.

The electric potential in the symmetry plane of the driven rod thus is dependent on only four parameters, namely: resistivity ρ of the ground, current I flowing into the rod, its length l within the ground, three data which are always given for a definite ground electrode, and the angle of vision β between the axis of the rod and the distance from the bottom of the rod to the point under consideration at the surface. For any point in this center plane β is the only variable parameter.

For large distance x of the point considered from the axis of the rod, the logarithm in equation 26 simplifies to

$$\log_e\left(\frac{1+\cos\beta}{\sin\beta}\right)\approx\cos\beta\approx\frac{l}{x} \tag{27}$$

and the potential is

$$V_\infty=\frac{\rho I}{2\pi x} \tag{28}$$

which is identical with that for a hemisphere.

On the other hand, for the surface of the rod, where the potential V is identical with the voltage E of the electrode, Figure 10 shows that for small radius a as compared to length l

$$\cot\frac{\beta}{2}\approx\frac{2l}{a} \tag{29}$$

Hence the resistance as quotient of voltage and current is

$$R=\frac{E}{I}=\frac{\rho}{2\pi l}\log_e\left(\frac{2l}{a}\right) \tag{30}$$

While the shape of the rod, determining the ratio l/a, is of minor significance since it forms only the argument of a logarithm, the length l of the rod is of major importance, for the ground resistance is nearly inversely proportional to the length.

A rod of radius $a=2.5$ centimeters and of length $l=6$ meters, dimensions often used in practice, driven into moist soil will present a resistance

$$R=\frac{10^2\text{ ohm-m}}{2\pi\cdot 6\text{m}}\log_e\left(\frac{2\cdot 6}{2.5\cdot 10^{-2}}\right)$$
$$=2.65\cdot\log_e 480=16\text{ ohms}$$

This value equals that for a hemisphere two meters in diameter.

equation 26 with respect to β and substitution of equation 32 into equation 31 gives the field strength

$$e=\frac{\rho I}{4\pi l}\frac{2}{\sin\beta}\frac{\cos^2\beta}{l}=\frac{\rho I}{2\pi l}\frac{\cos\beta}{x} \tag{33}$$

which is decreasing with both increased x and β.

For large distance x, $\cos\beta=l/x$, approximately, and the field strength

$$e_\infty=\frac{\rho I}{2\pi x^2} \tag{34}$$

becomes identical with that for a hemisphere. For small x, however, $\cos\beta\approx 1$, and the field strength

$$e_0=\frac{\rho I}{2\pi l x} \tag{35}$$

becomes much larger than for a hemisphere. This is due to the high concentration of the current around the small circumference of a rod.

Along the length of the rod the density of the current from rod to earth is nearly constant over the major part of the length, but actually increases at the bottom to about double the value at the center plane,

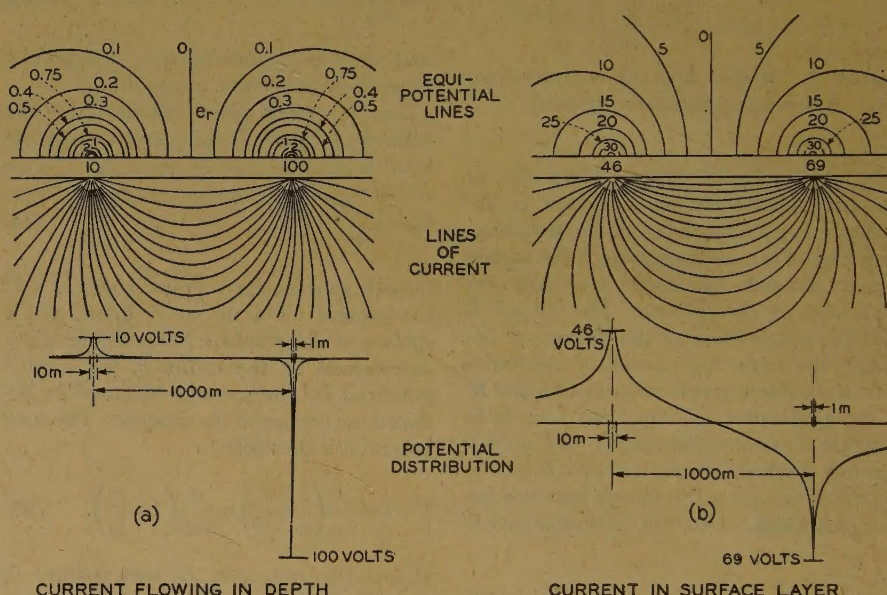


Figure 4. Flow of current between two ground electrodes

due to the point effect of the end of the rod.

Field Strength Around Rod Electrode. On the surface of the ground there develops, according to Figure 11, a field strength

$$e=\frac{dV}{dx}=\frac{dV}{d\beta}\frac{d\beta}{dx} \tag{31}$$

where the angle β is introduced as the variable. It is correlated to x by

$$\left.\begin{aligned}\tan\beta&=\frac{x}{l}\\ \frac{dx}{d\beta}&=\frac{l}{\cos^2\beta}\end{aligned}\right\} \tag{32}$$

where the last expression is merely the derivative of the first. Differentiation of

Simple Forms of Ground Electrodes. In a similar way the potential and the ground resistance of other forms of electrodes can be derived by superposition of spherical or cylindrical elements. Table II gives a survey of some simple forms of ground electrode. We see that a flat strip follows a relation quite like that of a circular rod and a strip thus is equivalent to a rod or a wire of a diameter equal to half the width of the strip.

The resistance of a ring of wire, having a periphery $2\pi b$, is only slightly greater than that of a straight wire of length $2l=2\pi b$,

the increase being due to the absence of the ends of the rod with their higher current density.

The resistance of a ground electrode near the surface of the earth is always twice the resistance of that electrode in greater depth, because the distribution of the cur-

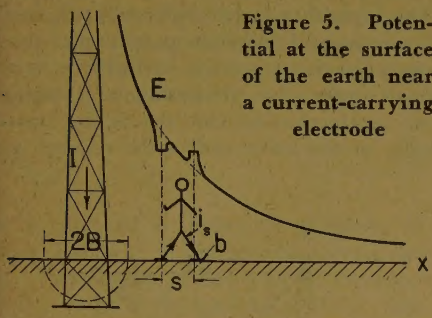


Figure 5. Potential at the surface of the earth near a current-carrying electrode

rent through the upper semispace is cut off.

As all the equations show, the resistance is determined primarily by the largest dimension of the electrode and only to a minor extent by the smaller dimensions, like cross section or thickness. Thus the surface of the electrode is unimportant and only the linear extension matters.

The simplest method for determining the resistance of a complicated shape of ground electrode, as for example the tower footing of a high-voltage line, or of a radio antenna, often consists in measuring the resistance of a scale model of the structure in an electrolytic trough. Then the resistance of the actual device is lower in the ratio of the linear dimensions and higher in the ratio of the resistivities of the surrounding medium. The radius of the equivalent hemisphere is always a convenient means of comparison.

Four-Point-Star Electrode. For some structures frequently used which are composed of several rods or wires, it is convenient to derive analytical formulas. In a four-point-star electrode, as in Figure 12, the self-potential of every straight wire of length $2l$ is, according to equations 26 and 29,

$$V_0=\frac{\rho I}{2\pi l}\log_e\left(\frac{2l}{a}\right) \tag{36}$$

This is to be increased by the mutual potential between the transverse wires of the cross. Equation 26 gives the potential of a wire of length $2l$ in its center plane. For angles $\beta \leq 45$ degrees, as in Figure 12,

$$\cot\frac{\beta}{2}\gtrless\frac{2l}{x} \tag{37}$$

The mean value of the logarithm of $2l/x$ over the length l of the wire is

$$\frac{1}{l}\int_0^l \log_e\left(\frac{2l}{x}\right)dx=-2\int_\infty^2 \log_e \xi\cdot d\frac{1}{\xi} = -2\int_\infty^2 \frac{\log_e \xi\cdot d\xi}{\xi^2}=2\left[\frac{\log_e\xi}{\xi}+\frac{1}{\xi}\right]_\infty^2 = \log_e 2+1 \tag{38}$$

Thus the mean mutual potential between the crossed wires is

$$V_1\gtrless\frac{\rho I}{2\pi l}(\log_e 2+1) \tag{39}$$

The voltage E of every conductor is given by the sum of the potentials or

$$E=V_0+V_1\approx\frac{\rho I}{2\pi l}\left[\log_e\left(\frac{2l}{a}\right)+\log_e 2+1\right] \tag{40}$$

and therefore the resistance to ground of the entire four-point-star electrode is

$$R=\frac{E}{4I}\approx\frac{\rho}{8\pi l}\left[\log_e\left(\frac{4l}{a}\right)+1\right] \tag{41}$$

If such a star of wires is embedded near the surface of the earth at a depth small compared with the length dimension of the electrode, the ground resistance is twice that of equation 41 as indicated in the last example of Table II.

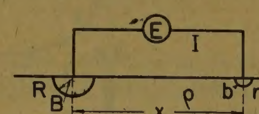


Figure 6. Measurement of the resistivity of the soil

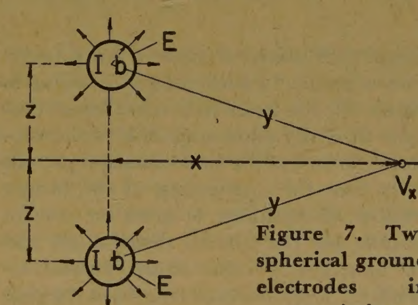


Figure 7. Two spherical ground electrodes in proximity

The value of the resistance of equation 41, by the addition of unity to the logarithm in the bracket, is slightly greater than for a straight wire of length $4l$. This increase is due to the mutual influence of the current distributions in the ground caused by neighboring parts of the entire electrode. With more star wires than four, such influence increases, preventing the resistance from being reduced in proportion to the increase of the number of the wires. For many wires, finally forming a circular disk, the resistance approaches

$$R=\frac{\rho}{8l} \tag{42}$$

For average values of the ratio radius to length of the wire, a comparison of equation 42 with equation 41 shows that by increasing the number of radial wires to infinity the resistance reduces to only

$$\frac{R^0}{R^+}=\frac{\pi}{\log_e\left(\frac{4l}{a}\right)+1}\approx\frac{\pi}{9.3}\approx\frac{1}{3} \tag{43}$$

of that of the simple four-wire star. The gain with increasing number of wires is not very great.

Multiple Rod Electrodes. Another combined electrode frequently used, namely, multiple driven rods connected in parallel, is shown in Figure 13. The potential at the earth's surface of every rod again is given by the general equation 26. The voltage at each of the electrodes is given by the sum of all the potentials produced by the rod considered and all the other rods. For rod number one, for example, the voltage is

$$E_1=\frac{\rho}{2\pi l}\left[I_1\log_e\left(\cot\frac{\beta_1}{2}\right)+I_2\log_e\left(\cot\frac{\beta_2}{2}\right)+\dots\right] \tag{44}$$

The currents of the rods are not yet determined, but for the sake of simplicity the resistivity of the soil and the length of all the rods have been taken as uniform. As many equations of this type can be developed as there are rods in the electrode, the angles β signifying always the angles of vision from the bottom of each rod toward the top of the rod considered as seen by Figure 13. Therefore, for any arrangement of driven rods a sufficient number of equations is obtained to determine the distribution of the currents among the individual rods of the electrode.

The first cotangent of equation 44 refers to the rod considered and can be evaluated by equation 29. The further cotangents, which refer to the other rods, can be expressed, as shown in Figure 13, by the ratio of the length l of the rod to a distance s_n, cut off by the angle $\beta/2$ on the distance S_n between the rods. Thus

$$\left.\begin{aligned}\cot\frac{\beta_1}{2}&=\frac{l}{a/2}\\ \cot\frac{\beta_n}{2}&=\frac{l}{s_n}\end{aligned}\right\} \tag{45}$$

If the rods are connected by zero resistance and are located symmetrically with

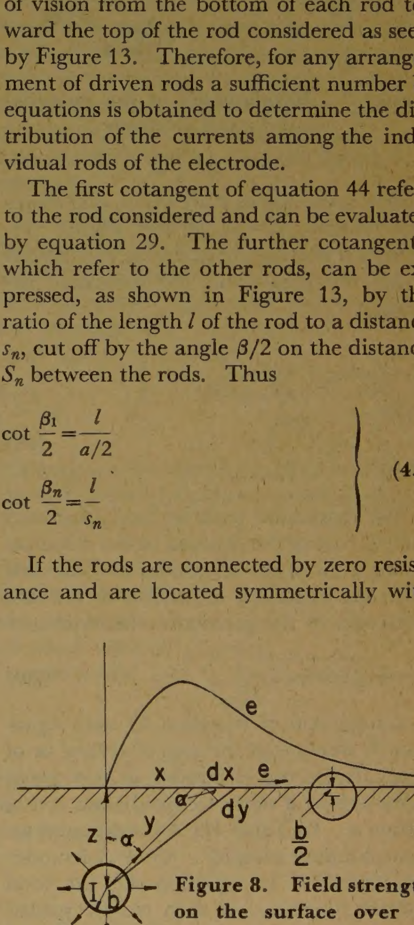


Figure 8. Field strength on the surface over a depth electrode

respect to one another, the voltages and currents are

$$E_1=E_2=E_3\ldots=E;\quad I_1=I_2=I_3\ldots=\frac{I}{n} \tag{46}$$

Therefore, with use of equation 45, all the equations 44 take the form

$$E=\frac{\rho}{2\pi l}\frac{I}{n}\left[\log_e\left(\frac{l}{a/2}\cdot\frac{l}{s_2}\cdot\frac{l}{s_3}\cdots\right)\right] \tag{47}$$

For each case equation 47 can be evaluated easily, but three significant examples may be considered in detail.

For large ratio S/l, with the rods distant from one another, evidently $\beta_n/2=45$ degrees and $s_n=l$. Thus all the quotients $l/s=1$, and the combined resistance is

$$R=\frac{E}{I}=\frac{1}{n}\cdot\frac{\rho}{2\pi l}\log_e\left(\frac{2l}{a}\right) \tag{48}$$

In this case the ohmic value is reduced in inverse proportion to the number of parallel rods.

For small ratio S/l, with the rods close together, the angles β are small, and therefore always $s_n=S_n/2$, see Figure 13. Hence, if the number of rods n is placed under the logarithm, the resistance becomes

$$R=\frac{\rho}{2\pi l}\log_e\left(\frac{2l}{\sqrt[n]{aS_2S_3S_4\ldots}}\right)$$
$$=\frac{\rho}{2\pi l}\log_e\left(\frac{2l}{A}\right) \tag{49}$$

In the right-hand term we have expressed the nth root of the product of the distances between all of the electrodes and the first electrode including the radius of the first electrode, by the geometric mean distance

$$A=\sqrt[n]{aS_2S_3S_4\ldots} \tag{50}$$

A comparison of equation 49 with equation 30 shows that the sum of several or of many driven rod electrodes in close proximity acts as if there were only one rod of radius A. In Table III A is evaluated for three simple examples. Since A is under the logarithm in equation 49, the total ground resistance of such closely spaced electrodes becomes diminished only slightly with increased number of rods.

For medium ratio $S/l=1$, where the rods are driven at distances equal to their length, evidently $\beta_n=45$ degrees, and thus $\cot\beta_n/2=2.4$. For example, if $n=3$ rods, the characteristic part of equation 47 becomes

$$\frac{1}{3}\log_e\left(\frac{l}{a/2}\cdot 2.4\cdot 2.4\right)$$

and for values of $l=6$ meters, $a=2.5$ centimeters, $\rho=10^2$ ohm-meters as in the former examples, the resistance is

$$R=\frac{2.65}{3}\log_e(480\cdot 2.4^2)=7.0\text{ ohms}$$

If the rods were far apart, $S=\infty$, the resistance would be $^{16}/_3=5.3$ ohms. Thus three rods with separation equal to their length experience a mutual influence which increases their resistance by 32 per cent.

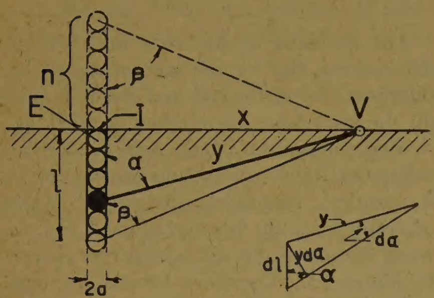


Figure 9. Development of the potential around a rod electrode

In order to obtain low ground resistance in bad soil of high resistivity, it is often necessary to arrange for quite a number of driven rods placed in lines or over an extended area. In such ground beds, as in Figure 14, the inner rods carry lower currents than the outer rods due to the mutual influence of the surrounding rods. In every case the application of the proper number of equations 44 gives the correct solution for the current distribution and the total ohmic value of the ground resistance. Even unequal lengths of the rods and different resistivity around the individual rods easily can be taken into account.

Figure 10 (left). Dimensions of a driven rod

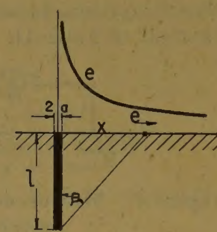


Figure 11 (right). Field strength on the surface around a driven rod

Depth Measurement. Frequently the resistivity ρ varies not only from rod to rod but also with the depth for each rod. In order to obtain a survey of such variation, it is useful to measure the ground resistance during the driving of the individual rods.

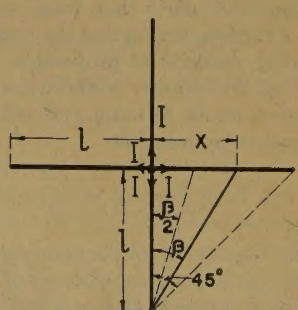


Figure 12. Four-point-star electrode in the ground

The ground conductance of a rod, as reciprocal of the resistance, equation 30, is

$$G=\frac{2\pi l}{\rho\cdot\log_e\left(\frac{2l}{a}\right)} \tag{51}$$

As indicated in Figure 15, the increment of conductance with lengthening of the rod by an element dx is therefore

$$dG=\frac{2\pi\cdot dl}{\rho\cdot\log_e\left(\frac{2l}{a}\right)} \tag{52}$$

The logarithm is not differentiated since it was derived under the condition of constant resistivity and its variation is very small under any circumstances. During the depth measurement the actual resistivity at the lower end of the rod over an increment of length dx is, by equation 52,

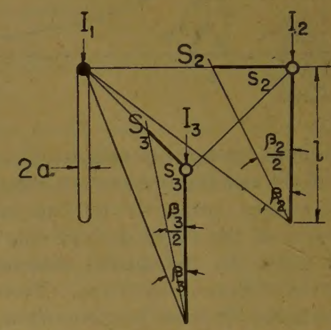


Figure 13. Driven rods in parallel

$$\rho=\frac{2\pi}{\log_e\left(\frac{2l}{a}\right)}\cdot\frac{dl}{dG} \tag{53}$$

Thus ρ is inversely proportional to the derivative of the conductance which is shown as dashed curve in Figure 16b.

With respect to the resistance R,

$$\left.\begin{aligned} G&=\frac{1}{R}\\ dG&=-\frac{dR}{R^2}\end{aligned}\right\} \tag{54}$$

and thus the resistivity at the lower end, dependent on the derivative of the resistance curve in Figure 16b, is

$$\rho=\frac{2\pi}{\log_e\left(\frac{2l}{a}\right)}\cdot\frac{R^2}{-\frac{dR}{dl}} \tag{55}$$

Figure 16a indicates that a small derivative is measured through a stratum of high resistivity, a large derivative through a stratum of low resistivity.

If a rod of radius $a=2.5$ centimeters is driven step by step into the depth and if at length $l=6$ meters, the resistance is measured as $R=16$ ohms and the derivative as $dR/dl=-0.15$ ohm per meter, the resistivity at that depth will be

$$\rho=\frac{2\pi}{\log_e(480)}\frac{16^2}{0.15}=174\text{ ohm-meter}$$

By such continuous measurements of resistance during the driving of a bed of rods, it is possible to obtain information about

the resistance strata of the earth in which the ground electrodes have to function.

HEATING OF THE GROUND

If a ground electrode is to be loaded continuously, or even over a short time only, the temperature rise θ of the soil must be considered in order to avoid an overloading which might evaporate the moisture. The current density about a spherical electrode with radius B embedded in the ground varies over the distance x as

$$i=\frac{I}{4\pi x^2} \tag{56}$$

as is indicated in Figure 17. Thereby an amount of heat ρi^2 is produced in every element of volume, which may be considerable because of the high value of the resistivity ρ. This heat is partly stored in the volume elements of the ground, which have an average specific heat $\gamma\approx 1.75\cdot 10^6$ ws/m^3C (watt-seconds/meter³·degrees centigrade); partly conducted from higher to lower temperature within the ground, the average heat conductivity being $\lambda\approx 1.2$ w/mC (watts/meter·degrees centigrade). Although these two thermal constants of the soil are of major significance, their actual values seldom have been measured accurately.

The differential equation of the radial heat conduction about a sphere is

$$\gamma\frac{d\theta}{dt}-\frac{\lambda}{x}\frac{d^2(x\theta)}{dx^2}=\rho i^2 \tag{57}$$

It is difficult to obtain a general solution of this equation since i varies with x. However, we can discuss two interesting phases of the heating, giving particular integrals, namely the steady state and the short-time state.

Steady-State Heating. For continuous ground currents the time derivative in equation 57 vanishes, and the differential equation becomes

Figure 14. Extended bed of rod electrodes

$$\lambda\frac{d^2(x\theta)}{dx^2}+\frac{\rho}{x^3}\left(\frac{I}{4\pi}\right)^2=0 \tag{58}$$

With two simple integrations the solution for the temperature distribution over distance x becomes

$$\theta=\frac{\rho}{\lambda}\left(\frac{I^2}{4\pi}\right)\cdot\frac{1}{x}\left(\frac{1}{B}-\frac{1}{2x}\right) \tag{59}$$

which is plotted against x in Figure 17. The maximum earth temperature at the electrode with $x=B$ is

$$\theta_B=\frac{1}{2}\frac{\rho}{\lambda}\left(\frac{I}{4\pi B}\right)^2 \tag{60}$$

and depends only on the two constants ρ and λ of the ground and on the linear cur-

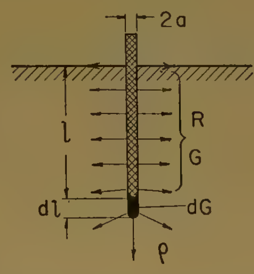


Figure 15. Increment of ground conductance with length of a rod

rent density I/B. The admissible current to ground from the spherical electrode is therefore

$$I=4\pi B\sqrt{2\frac{\lambda}{\rho}\theta}=\frac{1}{R}\sqrt{2\rho\lambda\theta} \tag{61}$$

where the right-hand term is obtained by substituting the resistance $R=\rho/4\pi B$. The current-carrying capacity of the electrode is thus determined, in addition to the ground constants, by resistance and temperature rise θ only.

Since the heat flow and the current distribution around electrodes of any shape follow the same mathematical law, namely Laplace's differential equation, the right-hand expression of equation 61 is valid not only for spherical electrodes but for any

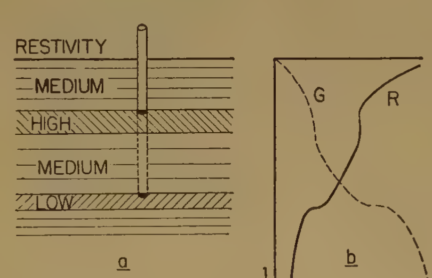


Figure 16. Measurement of rod resistance against depth

shape of electrode whether it be a rod, a ring, a disk, or a more complicated form. Therefore, if the resistance is known, which differs with the shape, the continuous current-carrying capacity can be determined easily.

The voltage at the ground electrode, measured from the metal to a far distant point is, from the last term of equation 61

$$E=IR=\sqrt{2\rho\lambda\theta} \tag{62}$$

Besides the ground constants E depends only on the temperature rise in the steady state. Conversely, the voltage applied to a ground electrode determines its steady-state temperature. These conclusions are true for any shape of electrode.

As an example, for $\theta=60$ degrees centigrade in moist soil,

$$E=\sqrt{2\cdot 10^2\cdot 1.2\cdot 60}=120 \text{ volts}$$

This voltage must not be surpassed if that temperature rise is not to be exceeded.

The admissible current density at the surface of the ground electrode, where the highest temperature exists, determined for a spherical electrode from equation 61 is

$$i=\frac{I}{4\pi B^2}=\frac{1}{B}\sqrt{2\frac{\lambda}{\rho}\theta} \tag{63}$$

For the former example

$$i=\frac{1}{1\text{m}}\sqrt{2\frac{1.2}{10^2}60}=1.2 \text{ amperes per square meter}$$

Thus the current density permitted for continuous loading of the electrode is fairly small. The soil surrounding the electrode must not heat up to 100 degrees centigrade, since the moisture would then evaporate completely, and the current would be interrupted by the enormously increased resistance.

Short-Time Heating. For short-time loading of the ground electrode the second member of equation 57, the heat-conduction term, plays only a minor role and thus may be neglected. The remaining differential equation then becomes

$$\frac{d\theta}{dt}=\frac{\rho}{\gamma}i^2 \tag{64}$$

The temperature rise thus follows the same law as it does with ordinary linear conduc-

Figure 17. Temperature distribution around a spherical ground electrode

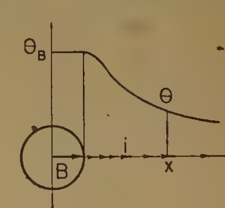
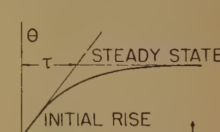


Figure 18. Change with time of ground temperature



tors. If resistivity ρ and specific heat γ are constant, the temperature rise is linear with time, and thus the admissible current density is

$$i=\sqrt{\frac{\gamma}{\rho}\frac{\theta}{t}} \tag{65}$$

Because the length dimension x does not appear in equation 64, this differential equation is true for every volume element of the soil, independent of the pattern of flow of the current. Hence equation 65 is valid for any shape of the ground electrode.

For example, an electrode in moist soil and for a temperature rise not exceeding 60 degrees centigrade is permitted to be loaded over a period of 100 seconds by a current density

$$i=\sqrt{\frac{1.75\times10^{6}}{10^{2}}\cdot\frac{60}{100}}=100 \text{ amperes per square meter}$$

which is a fairly high value. For sandy soil with ten times higher resistivity a short-time loading at the same current density is permitted for ten seconds only. Higher current density or longer loading period would evaporate the moisture of the soil in a very short time, and an explosion of the space surrounding the electrode might follow, and is sometimes experienced.

The voltage at the electrode with short-time loading may attain a very high value. In the example for moist soil, the voltage is higher than in the steady-state example by the ratio of the current densities, and therefore it reaches here the value

$$E=120\cdot\frac{100}{1.2}=10{,}000 \text{ volts}$$

The initial rise of temperature over a short time as given by equation 64 is shown in Figure 18. The final temperature rise, with fixed constants of the soil, would be given by equation 60, and also is indicated in Figure 18. The intermediate curve follows the complete differential equation 57 but is difficult to derive analytically. However, we can easily determine the time constant τ, defined as the time in which the linear initial rise would reach the steady-state temperature, see Figure 18. For this intersection we have, with use of equations 60 and 64 and substitution in the former the current density for the current

$$\theta_{\text{steady}}=\frac{1}{2}\frac{\rho}{\lambda}B^2i^2=\frac{\rho}{\gamma}i^2\tau=\theta_{\text{rise}} \qquad (66)$$

Hence the time constant of heating for a spherical ground electrode and its surrounding soil is

$$\tau=\frac{1}{2}\frac{\gamma}{\lambda}B^2 \qquad (67)$$

In addition to the thermal constants of the soil, τ is dependent only on the square of the radius B. For other forms of electrodes the time-constant follows a similar form except that instead of B another characteristic dimension of the electrode must be used, being somewhere between the maximum and the minimum dimension of the electrode.

For example, for a sphere with radius $B=1$ meter the time constant is

$$\tau=\frac{1}{2}\frac{1.75\cdot10^{6}}{1.2}1^2=0.73\cdot10^{6}\text{ sec}=8.5\text{ days}$$

This is a very long period, due to the very low heat conductivity of the soil, but it is completely in accord with test results.

LINEARLY EXTENDED FIELDS

Buried Long Electrodes. In the foregoing discussions there have been considered only electrodes with constant voltage over their length. However, with the use of long electrodes such as wires or strips, cable sheaths, railroad or tramway tracks, pipe lines, or similar ground electrodes of considerable length, the current may suffer an ohmic drop due to the internal resistance r of the electrode before it spreads out in the resistance R of the ground. Figure 19 shows how the total current I_0 enters a ground wire, follows its length, gradually being attenuated, and leaving the wire as spatial current i. There are measured now the wire current I in amperes, the ground current i in amperes per meter, the resistance r of the electrode in ohms per meter, and the resistance R of the ground in ohm-meters. The resistance R may vary slightly over the length x of the wire due to the concentration of the ground-current density i near the end points. However, taking a mean value over the length is sufficiently accurate for this problem.

According to Kirchhoff's laws, at any point x of the long wire the sum of the inflowing and outflowing current within the wire and the current flowing to ground is zero. On the other hand, the voltage over a narrow rectangle formed by a wire resistance element $r\cdot dx$ and the two adjacent ground resistances R is zero. Therefore

$$\left.\begin{aligned} i+\frac{dI}{dx}&=0\\ R\frac{di}{dx}+rI&=0\end{aligned}\right\} \qquad (68)$$

from which can be obtained the differential equation, for the wire current I, for example,

$$\frac{d^2I}{dx^2}-\frac{r}{R}I=0 \qquad (69)$$

If we reckon x from the far end of the wire of length l, and write for abbreviation

$$\delta=\sqrt{\frac{r}{R}} \qquad (70)$$

the solution of equation 69 gives the current distribution in the wire as

$$I=\frac{\sinh\delta x}{\sinh\delta l}I_0 \qquad (71)$$

Correspondingly, the ground-current distribution results from the first equation 68 as

$$i=\delta\cdot\frac{\cosh\delta x}{\sinh\delta l}I_0 \qquad (72)$$

The variation of both currents along the length x of the electrode is shown in Figure 19b.

Near the terminal of a long conductor the hyperbolic distributions have a space constant X defined by the subtangent as

$$X=\frac{1}{\delta}=\sqrt{\frac{R}{r}} \qquad (73)$$

If the electrode has a length of more than about $3X$, the ground current will have attenuated to an insignificant remainder over that length. Thus the effect of buried long electrodes is limited by gradual attenuation, determined by the ratio of wire to ground resistance, as seen by equation 73.

For low values of wire resistance r or length l the product δl is small and there is

$$\left.\begin{aligned}\sinh\delta l&\approx\delta l\\ \cosh\delta l&\approx1\end{aligned}\right\} \qquad (74)$$

Therefore

$$\left.\begin{aligned}I&=\frac{x}{l}I_0\\ i&=I_0/l\end{aligned}\right\} \qquad (75)$$

Table II. Resistance of Simple Forms of Ground Electrodes

Sphere:

$R=\frac{\rho}{4\pi B}$

Disk:

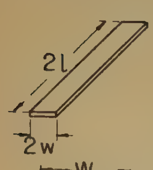
$R=\frac{\rho}{8b}$

Rod:

$R=\frac{\rho}{4\pi l}\log_e\left(\frac{2l}{a}\right)$

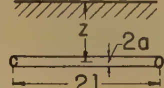
Ring:

$R=\frac{\rho}{4\pi^2b}\log_e\left(\frac{8b}{a}\right)$



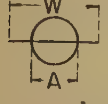
Strip:

$R=\frac{\rho}{4\pi l}\log_e\left(\frac{4l}{w}\right)$



Deep wire:

$R_z=R\left[1+\frac{\log_e\left(\frac{l}{z}\right)}{\log_e\left(\frac{2l}{a}\right)}\right]$



Equivalent rod and strip:

$A=W/2$

Surface electrode:

$R_0=2R$

Table III. Geometric Mean Distances for Parallel-Rod Electrodes

n =	Arrangement	Geometric Mean Distance
2		$A=\sqrt{aS}$
3		$A=\sqrt[3]{aS^2}$
4		$A=\sqrt[4]{\sqrt{2}aS^3}$

Table IV. Resistance and Dimensions of Equivalent Ground-Return Conductor

$f=$	50	150	500	5,000	c
$R=$	0.05	0.15	0.5	5	Ω/km
$d=$	2.1	1.3	0.7	0.2	cm
$D=$	800	460	250	80	m

Thus the wire current decreases linearly with x and the ground current is uniformly distributed over l, as is the case with constant-voltage electrodes.

For large values of wire resistance r or length l, excluding, however, the point $x=0$ and its neighborhood, there is

$$\sinh \delta x \approx \cosh \delta x \approx \epsilon^{\delta x}/2 \tag{76}$$

Therefore, according to equations 71 and 72, both currents I and i attenuate exponentially from their original values, and the ground current is related to the wire current by

$$i=\sqrt{\frac{r}{R}}I \tag{77}$$

The resistance R_0 of the entire electrode to ground is given by the ratio of voltage E to terminal current I_0, the voltage being equal to the ohmic drop of the initial ground current i_0 across its ground resistance R. Thus

$$R_0=\frac{E}{I_0}=\frac{Ri_0}{I_0} \tag{78}$$

Using equation 72 at the terminal $x=l$, and substituting equation 70, the ground resistance of an extended buried electrode is generally

$$R_0=\sqrt{rR}\cdot\coth \delta l \tag{79}$$

and for large δl, where coth δl becomes 1, is simply

$$R_0=\sqrt{rR} \tag{80}$$

Hence the ground resistance of a long electrode depends equally on the electrode's metallic resistance electrode and the soil's resistance soil, the geometric mean value being effective.

For example, for the lead sheath of a cable of radius $a=2$ centimeters and length $l=1$ kilometer buried in moist soil close to the surface of the earth, the ground resistance of each meter of cable, using equation 30, is

$$R=\frac{\rho}{2\pi}\log_\epsilon\left(\frac{l}{a}\right)=\frac{10^2}{2\pi}\log_\epsilon\left(\frac{10^3}{2\cdot 10^{-2}}\right)$$
$$=170 \text{ ohm-meters}$$

This would give a total resistance of the lead sheath to ground of $R/l=0.17$ ohm, if the voltage of the electrode were kept constant over the entire length. The resistance of the lead sheath is about $r=1.5\cdot 10^{-3}$ ohms per meter, giving a space constant

$$X=\sqrt{\frac{170}{1.5\cdot 10^{-3}}}=337 \text{ meters}$$

and since coth $1{,}000/337=1$, a resultant resistance of lead sheath and ground

$$R_0=\sqrt{1.5\cdot 10^{-3}\cdot 170}=0.5 \text{ ohm}$$

Hence the voltage on the sheath will decrease over the cable length to nearly zero and the effective resistance R_0 is three times as great as were this voltage constant.

Separate Conductors Buried in the Earth. If cross section and conductance of the electrode are considerable, the currents may be led to much greater distances. Such conductors sometimes play a tricky role, even if they are not directly connected to any electric system. They collect the streamlines of current in one region and carry them into a distant region of the ground.

For a long pipe in an extended ground field, as in Figure 20, an equilibrium is established between the parallel current density i_1 in the ground and i_2 in the pipe extending in the direction of the streamlines. The field strengths e in soil and conductor are the same, and since the current density is field strength over resistivity, the ratio of the current densities in electrode and soil is

$$\frac{i_2}{i_1}=\frac{e_2/\rho_2}{e_1/\rho_1}=\frac{\rho_1}{\rho_2} \tag{81}$$

Thus the current densities are inversely as the resistivities.

For a steel conductor buried in moist ground, there must be expected

$$\frac{i_{\text{steel}}}{i_{\text{soil}}}=\frac{10^2}{10^{-7}}=10$$

and a still greater ratio if the ground is dry. Therefore a steel pipe of ten square centimeters cross section can collect current from a ground area of

$$10^9\,\frac{10}{10^4}=10^6 \text{ square meters }=1 \text{ square kilometer}$$

of cross section. Hence such a pipe is able to suck ground current from wide areas and carry it to distant points.

For a short pipe in an extended ground field, as in Figure 21, streamlines of current will enter at one end and leave from the other end. The voltage over the length $2l$ of the pipe in the undisturbed ground field is

$$E=2le=2l\rho i \tag{82}$$

This voltage works on the entrance and exit ground resistance of each end of the pipe and produces a current I in the center of the pipe, the metallic resistance being insignificant. Thus, with use of equation 30,

$$E=2RI=\frac{2\rho I}{2\pi l}\log_\epsilon\left(\frac{2l}{a}\right) \tag{83}$$

Equating equations 82 and 83 gives a pipe current

$$I=\frac{2\pi l^2}{\log_\epsilon\left(\frac{2l}{a}\right)}i \tag{84}$$

related to the current density i in the undisturbed underground field and independent of resistivity ρ. If groups of parallel pipes are present instead of a single pipe, their geometric mean distance A rather than the radius a of a single pipe is to be used, see equation 50.

For example, a pipe of half length $l=100$ meters and radius $a=10$ centimeters will collect from a field of current density $i=10^{-4}$ amperes per square meter a maximum current

$$I=\frac{2\pi 100^2}{\log_\epsilon\left(\frac{2\cdot 100}{0.1}\right)}10^{-4}=0.83 \text{ ampere}$$

Figure 21 shows that with such a pipe the current lines over a circular area are collected, the diameter D of which can be found from

$$I=\frac{\pi}{4}D^2 i=\frac{2\pi l^2}{\log_\epsilon\left(\frac{2l}{a}\right)}i \tag{85}$$

Thus the diameter of collection is

$$D=2l\sqrt{\frac{2}{\log_\epsilon\left(\frac{2l}{a}\right)}}=2l\sqrt{\frac{2}{6\rightarrow 10}}\approx l \tag{86}$$

if an average value of the logarithm of about 8 is used.

Such pipes may suffer electrolytic corrosion if the d-c density exceeds a value of the order of 0.1 ampere per square meter. The average entrance or exit current density over the surface of the pipe in Figure 21 is

$$\bar{\imath}=\frac{I}{2\pi al}=\frac{l/a}{\log_\epsilon\left(\frac{2l}{a}\right)}i \tag{87}$$

showing a high current concentration over the density i in the free field, and this may even be doubled at the pipe ends. For the

example the mean current density along the pipe is

$$\bar{i}=\frac{100/0.1}{7.6}\,i=132\ i=132\cdot10^{-4}=1.32\cdot10^{-2}$$
ampere per square meter

which is under the corrosion limit.

For a long pipe passing through a limited ground field, as in Figure 22, the problem of the development of the current lines in space is highly complex. Ollendorf found an approximate solution for the maximum current I_p developed in a pipe of radius a which passes at distance S an electrode from which a current I enters the ground, namely,

$$I_p=\frac{\sinh^{-1}\sqrt{\dfrac{S}{a}}}{\log_e\left(4\dfrac{S}{a}\right)}I \tag{88}$$

The current collected in this way, as shown by Figure 22, may spread out over vast distances depending on the resistivities of ground and pipe. The maximum surface density of the current entering the pipe, according to Ollendorf's solution, is

$$i=\frac{I}{\pi aS}\frac{1}{\log_e\left(4\dfrac{S}{a}\right)} \tag{89}$$

With current $I=100$ amperes entering the ground through an electrode at distance $S=30$ meters from a pipe the current density entering the pipe of radius $a=10$ centimeters will be

$$i=\frac{100}{\pi\cdot0.1\cdot30}\frac{1}{\log_e\left(4\dfrac{30}{0.1}\right)}=1.5 \text{ amperes per square meter}$$

a value which will produce severe electrolytic corrosion, if it is direct current.

Alternating Return Current Under Transmission Lines. This article has dealt up to now with the effects of the resistivity of the ground without considering any inductive action of the currents. These derivations are true for direct current flowing through the ground. However, they are equally valid for alternating current as far as the proximity of the electrodes is concerned, for here the inductive action of the changing magnetic fields is negligible compared with the effect of the high resistivity of the ground. Only for extremely rapid change with time this may be modified, as will be shown later.

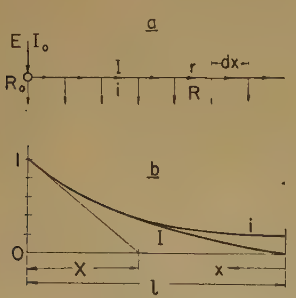


Figure 19. Current distribution along an extended electrode

If ground current flows over a long distance between entrance and exit electrode, the current lines in the d-c case spread out over such a broad transverse area in the earth, as seen by Figure 4a, that the resistance is negligibly small except for the proximity of the electrodes, as previously shown. For alternating current, however, with decreasing effect of the resistance the self-inductive action of the magnetic field becomes preponderant, and thus the distribution of the current lines in the ground under a-c conditions will be determined mainly by the inductive effects. It is well known that the currents in such a case are so distributed that the energy of the magnetic field and thereby the self-inductance tend to become a minimum.

Therefore an alternating return current in the ground under a long transmission line will not spread to a great distance, as direct current does, but will concentrate on paths in proximity to the transmission line, as shown in Figure 23. Hence the distribution of alternating current in the ground is governed by the laws of skin effect, laterally as well as in depth. Because of the high resistivity of the soil, however, much larger dimensions come into consideration than with metallic conductors.

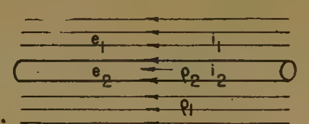


Figure 20. Long pipe embedded in an extended ground field

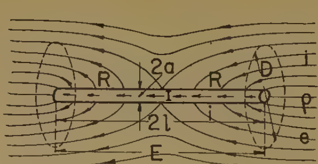


Figure 21. Short pipe buried in an extended ground field

A single transmission line, as in Figure 23, will develop concentric magnetic lines of force of nearly circular form, at least in the neighborhood of the line, where the magnetic effect of the return current in the ground is of lesser importance because of its low density. Therefore the phenomena will be dependent primarily on the distance y from the center of the wire, carrying the total current I, to the point considered at the earth. The error caused by this assumption is usually small as compared to that caused by subsoil heterogeneity. With angular frequency ω, the differential equation of the distribution over the ground of the current density i then is

$$\frac{1}{y}\frac{d}{dy}\left(y\frac{di}{dy}\right)-j\cdot2\pi\mu\frac{\omega}{\rho}i=0 \tag{90}$$

a complex relation similar to that for other skin-effect problems. The value $\mu=10^{-7}$ is the permeability of nonmagnetic material in the meter-kilogram-second system.

The solution of this equation is given by a Bessel function H_0 of zero order. With abbreviation

$$\kappa=\sqrt{2\pi\mu\frac{\omega}{\rho}} \tag{91}$$

the current density, up to frequencies of about 5,000 cycles per second, is

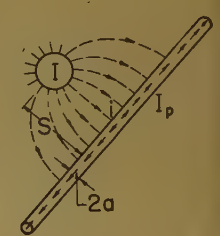
$$i=\frac{\kappa^2}{2}I\cdot H_0(\sqrt{j}\,\kappa y) \tag{92}$$

where the argument of the Bessel function depending on distance y is complex, indicating that the distribution of the return current through the ground occurs in waves.

For two instants, 90 degrees displaced in time, the values of the Bessel function H_0 are shown in Figure 23, determining the current density against distance. From numerical tables of this Bessel function it can be derived that directly under an overhead power line of height $y=h=10$ meters the current density at 60 cycles per second in moist soil of $\rho=10^2$ ohm-meters is nearly

$i=3\cdot I$ in amperes per square kilometer

Figure 22. Long pipe running through a limited ground field



Thus for every ampere of line current there develops a current density of three amperes per square kilometer in the ground under the line, and naturally a still smaller current density at greater distances.

The current density in the ground decreases to an insignificant magnitude at a distance of about $y=3/\kappa$, as seen by a discussion of the function H_0. Hence for moist soil the zone of extinction is

For current of 60 cycles per second about 2,000 meters,

For current of 500 cycles per second about 700 meters,

and a still smaller distance for higher frequencies. Thus a return current under a transmission line flows only in a moderately broad zone through the ground under and to both sides of the line. This zone follows any trace of the line, it may be straight or curved, since the distribution of the return current always seeks to reduce the self-inductance to a minimum and therefore to avoid any open loop between line current and return path.

The field strength in the ground, with use of equations 91 and 92, is

$$e=\rho i=\pi\mu\omega I\cdot H_0(\sqrt{j}\;\kappa y) \tag{93}$$

Therefore the voltage over a distance l on the ground surface immediately under the transmission line, namely for $y=h$, is

$$E=\pi\mu\omega Il\cdot H_0(\sqrt{j}\;\kappa h)\approx \omega Il\left[\frac{\pi}{2}+j2\log_e\left(\frac{1.12}{\kappa h}\right)\right]10^{-7} \tag{94}$$

Herein an asymptotic approximation of the Bessel function is used for small values of the complex argument, resulting in a form which has distinct real and imaginary components. The voltage over the ground, therefore, is complex, consisting of two perpendicular vector components, where

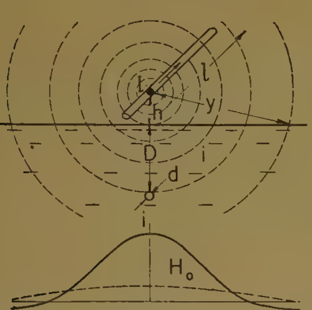


Figure 23. Distribution of ground-return currents under a-c transmission lines

the real part gives the effective resistance of the return current

$$R=\frac{\pi}{2}\mu\omega l=\pi^2 fl\cdot 10^{-7} \tag{95}$$

while the imaginary part determines the effective self-inductance

$$L=2l\cdot\log_e\left(\frac{0.178}{h}\sqrt{\frac{\rho}{f}}\right)\cdot 10^{-7} \tag{96}$$

In the last two equations the frequency f per second is used instead of the angular frequency ω.

Hence alternating return current through the ground experiences a resistance which is proportional to length l and to frequency f but independent of resistivity ρ of the soil. Table IV gives the return resistance R in ohms per kilometer for various frequencies in moist soil of $\rho=10^2$ ohm-meters. The values are not unimportant for heavier currents or for frequencies above the power range. The same return resistance would be attained by a fictitious copper wire of an equivalent diameter d as given in the third line of Table IV.

The self-inductance of the return currents as given by equation 96 is also proportional to length l, depends slightly on the height h of the transmission line and, to an even lesser degree, on resistivity and frequency, these being under the logarithm of a square root. Thus for a large range of such data the self-inductance is very nearly

$L=0.9$ millihenry per kilometer

or

$\omega L=0.34$ ohm per kilometer

This self-inductance of the ground current adds to the self-inductance of the line current, which is also determined by a well-known logarithmic relation. So is also the self-inductance of a fictitious return conductor of diameter d and depth D under the surface, the ohmic and inductive effects of which may be taken equivalent to those of the ground return. By comparison of equation 96 with the self-inductance of such an ideal return system, the equivalent depth can be determined. We see from the last two lines in Table IV that the equivalent diameter d of a copper return wire would be of the order of two centimeters for 50 cycles per second but of only 0.2 centimeters for 5,000 cycles per second. On the other hand, the equivalent depth D would vary from 800 meters to 80 meters over the same frequency range.

Inductive Interference of Parallel Lines. If at a distance y a neighboring line runs parallel to the transmission line with cur-

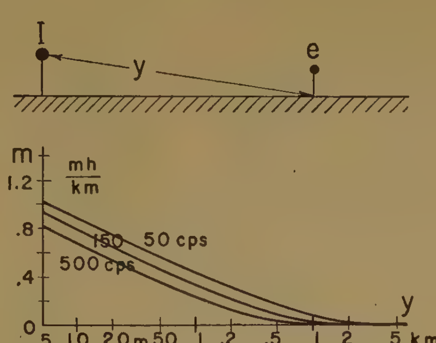


Figure 24. Mutual inductance between lines with ground return

rent I returning through the ground, as shown in Figure 24, and the two ends of the secondary line are directly or indirectly grounded, then a voltage develops over a length l of this line according to equation 93

$$E=\pi\mu\omega Il\cdot H_0(\sqrt{j}\;\kappa y) \tag{97}$$

This is a voltage of mutual effect between primary and secondary line caused mainly by action of the ground-return currents and their magnetic field.

Hence the coefficient of mutual induction for the unit length of both lines is

$$m=\pi\cdot H_0(\sqrt{j}\;\kappa y)\cdot 10^{-7} \tag{98}$$

Since the value of the Bessel function H_0 is complex, this mutual inductance has amplitude and phase angle in contrast to the straight inductance of two linear circuits alone. This is effected by the alternating currents produced in a spatially extended third conductor, namely, the ground. Figure 24 shows the amplitude of the mutual inductance in millihenrys per kilometer dependent on distance y between primary and secondary circuit for various frequencies, if the resistivity of the intermediate ground is $\rho=10^2$ ohm-meters, as for moist soil. In all practical cases the resistivity will not be uniform over surface and depth of the ground between and around such transmission lines, and thus an average resistivity of the entire field should be taken into account. High resistivity of the underground increases the action to a greater distance.

If, for example, a short-circuit current $I=500$ amperes in a power line flows through an arcing ground to earth and returns through it to the grounded neutral of the power station, then, according to equation 97, a telephone line at a distance $y=1$ kilometer, running parallel to the power line over a length $l=10$ kilometers and using the ground for return, will suffer a voltage of

$$E=\pi\cdot 10^{-7}\cdot 377\cdot 500\cdot 10\cdot 10^3\cdot 0.20=118 \text{ volts}$$

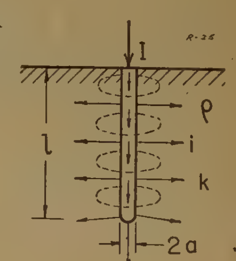
a value which would annihilate any telephone conversation.

IMPULSE CHARACTERISTICS

Performance of Driven Rods. It may be asked how closely the current in an electrode and the surrounding ground can follow a rapid variation of the voltage. The best criterion for this is given by the values of the electric time-constants and the natural periods of oscillation.

In Figure 25 the current I impinges on the rod electrode and enters the ground,

Figure 25. Impulse current spreading from driven rod



which in addition to its resistivity has a dielectric constant k. Thus in parallel to the conductive current in the ground there develops a capacitive or displacement current in case the electrode voltage changes with time. The displacement current follows exactly the lines of the conductive current, and thus the ground electrode will have a capacitance, as reciprocal to the resistance of equation 30,

$$C=\frac{kl}{2\cdot\log_e\left(\frac{2l}{a}\right)}\cdot\frac{10^{-9}}{9}\text{ farad} \tag{99}$$

The currents in electrode and ground, furthermore, form a magnetic field indicated by the dashed lines in Figure 25.

This field is highest where the current is most concentrated, namely around the rod electrode. Therefore the inductance of the ground currents is mainly given by the distribution of the currents in the rod, having full value at the top and decreasing to zero at the bottom. The inductance of such a rod is

$$L = 2l \cdot \log_\epsilon\left(\frac{2l}{a}\right) \cdot 10^{-7} \text{ henry} \qquad (100)$$

The capacitive time constant of any circuit element is given by the product of capacitance and resistance, and thus a rod electrode has a time constant

$$\tau_C = CR = \frac{\rho k}{4\pi \cdot 9 \cdot 10^9} \qquad (101)$$

It depends only on resistivity and dielectric constant k, the value of which for ordinary soil may be of the order of 9, in view of the high value for water.

For example, for moist soil

$$\tau_C = \frac{10^2 \cdot 9}{4\pi \cdot 9 \cdot 10^9} = 8 \cdot 10^{-9} \text{ second}$$

which is an extremely small value. For rock as underground the value is about $8 \cdot 10^{-7}$ second.

The inductive time constant as quotient of self-inductance and resistance is

$$\tau_L = \frac{L}{R} = 4\pi \frac{l^2}{\rho} \cdot 10^{-7} \qquad (102)$$

It is proportional to the square of the length l of the electrode, and therefore greatly dependent on this dimension. For example, for a rod of $l = 6$ meters in moist soil

$$\tau_L = 4\pi \frac{6^2}{10^2} \cdot 10^{-7} = 4.5 \cdot 10^{-7} \text{ second}$$

For the same electrode in rock the value is $4.5 \cdot 10^{-9}$ second. Both these values are likewise very small.

Since all these numerical values are less than the time usually assumed for the shortest possible lightning impulse impinging on a driven rod, current and voltage in the rod will follow such impressed impulse of the order of 10^{-6} seconds without any significant time delay and will behave as in the steady state. Hence capacitance and inductance of a driven rod of moderate length play no significant part even with rapid lightning phenomena.

The natural oscillations of which such a rod is capable have a period

$$T = 2\pi\sqrt{LC} = \frac{2\pi\sqrt{k}}{3 \cdot 10^8} \cdot l \qquad (103)$$

depending only on dielectric constant and length. For the same example, the natural period is

$$T = \frac{2\pi\sqrt{9}}{3 \cdot 10^8} \cdot 6 = 3.8 \cdot 10^{-7} \text{ seconds}$$

This also is beyond the duration usually assumed for lightning strokes, and indicates the frequency up to which the rod behaves as an ohmic resistance.

The damping of the free oscillations is determined by the value of the quotient of resistance and surge impedance in comparison to the value one half, namely,

$$\frac{R}{\sqrt{L/C}} = \frac{\rho\sqrt{k}}{120\pi l} \begin{cases} >{}^1\!/_2 \text{ periodic} \\ <{}^1\!/_2 \text{ aperiodic} \end{cases} \qquad (104)$$

For the same rod in moist soil

$$\frac{R}{\sqrt{L/C}} = \frac{10^2\sqrt{9}}{120\pi \cdot 6} = \frac{1}{7.5}$$

so that any natural oscillation would be aperiodically damped. For rock, however, the quotient assumes the value 13, indicating that here the driven rod can oscillate periodically.

An equivalent diagram is often convenient to represent the properties of a circuit element in a simplified form. In view of the foregoing numerical values there is no doubt that for low frequencies a driven rod and all its derived electrodes can be represented by a lumped resistance, as in Figure 26a. This remains true for a ground electrode of moderate length up to high and even very high frequencies. However, it should be noticed that a tower, or a lead, through which a lightning discharge reaches the electrode may have considerable self-inductance because of its height. This is indicated in Figure 26b. If the voltage at the rod electrode is very high, as is frequently the case with lightning discharges, the field strength at the rod becomes so great that the electric strength of the ground is broken down and sparks discharge from the rod into the neighboring ground thereby considerably decreasing the entire ground resistance. This performance is indicated in the equivalent diagram of Figure 26b by a spark by-pass to a part of the ground resistance.

If the discharge to the ground electrode is extremely rapid or the equivalent frequency is extremely high, of an order of more than 10^6 cycles per second, a considerable displacement current in the capacitance of the ground will parallel the conductive current in the resistance, and together with the self-inductance of both of these currents through the rod, will effect an equivalent diagram as in Figure 26c. The time-constants, the natural oscillations, and the damping of the electrode, as in equations 101 to 104, now will be determinative.

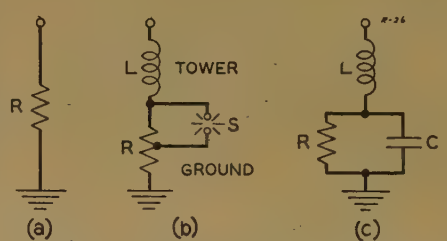


Figure 26. Equivalent circuits of ground electrodes over wide range of voltage and frequency

(*a*). *Low voltage, low frequency*
(*b*). *High voltage, high frequency*
(*c*). *Ultrahigh frequency*

Performance of Buried Wires. In ground electrodes of considerable length, as with buried long wires, the self-inductance will play a larger part with respect to impulse currents, since the inductive time constant, see equation 102, increases as the square of the length. The capacitive effect of the ground, see equation 101, will not change, however, and may be neglected. Since buried wires usually have substantial cross section, the internal resistance of the electrode also may be neglected in comparison to the self-inductance. Figure 27a shows the remaining data of the problem, namely, the wire current I in amperes, the ground current i in amperes per meter, the self-inductance L of the wire in henrys per meter, and the ground resistance R in ohm-meters.

Corresponding to the case where the wire resistance is taken into account, see Figure 18 and equation 68, the relations between the currents in the present example are

$$\left.\begin{aligned} i + \frac{dI}{dx} &= 0 \\ R\frac{di}{dx} + L\frac{dI}{dt} &= 0 \end{aligned}\right\} \qquad (105)$$

Their combination gives the differential equation for the current in the wire

$$\frac{d^2I}{dx^2} - \frac{L}{R}\frac{dI}{dt} = 0 \qquad (106)$$

and a corresponding equation for the ground current i. Equation 106 is the well-known differential equation of heat diffusion. A solution for a short impulse is

$$I = \frac{K}{\sqrt{t}}\,\epsilon^{-\frac{L}{R}\frac{x^2}{t}} \qquad (107)$$

where the amplitude is still free as determined by a constant K of integration, while the exponent depends, in addition to L and R, on the square of distance x and on time t. This function is plotted in Figure 27b against distance x and in Figure 28a against time t. Equation 107 represents an impulse curve over the time axis, which increases at first slowly and then steeply, reaches a maximum peak, and decreases gradually toward zero. Such a curve might well be used to approximate the time characteristic of a lightning discharge to ground which is known from many experimental investigations.

Figure 27b shows the manner in which the current in the wire, from a narrow zone in the beginning, spreads gradually

over the length of the wire. It is not necessary to identify the origins of x and of t in equation 107 with the origin of the lightning current. Figures 27 and 28 show that displacements in space x_0 and in time t_0 can be used for constants of the solution (107) and by proper selection of these every actual case can be approximated closely.

The points at which the spatial curves of Figure 27b are steepest determine the front zone of the attenuated propagating wave of current. Their location can be derived from equation 107 and is given by

$$\frac{L}{R}\frac{x^2}{t}=\frac{1}{2} \tag{108}$$

These points travel with a velocity

$$v=\frac{dx}{dt}=\frac{1}{4}\frac{R/L}{x}=\frac{10^7}{4\pi}\frac{\rho}{x} \tag{109}$$

where R/L is taken from equation 102, both data, however, being here related to the unit length. Hence the velocity of the front is not constant but decreases rapidly with distance x.

Buried long wires are often used as electric counterpoises additional to the tower footing conductance of high-voltage transmission lines, in case the resistivity of the soil is so high that it is difficult otherwise to obtain a low ground resistance. With a resistivity, therefore, of $\rho=10^3$ ohm-meters, the front velocity of the current wave will be, for example, at distance $x=10$ meters on the wire,

$$v=\frac{10^7}{4\pi}\frac{10^3}{10}=0.8\cdot10^8 \text{ meters per second}$$

This is about one-fourth the velocity of light, a velocity reached in straight conductors in air. In ground wires of considerable length, therefore, the joint effect of self-inductance and ground resistance leads to a lower and ever decreasing wave velocity.

The voltage at every point of the wire is determined by the ohmic drop of the ground current i in the ground resistance R. By using the first equation 105 and differentiating equation 107, the voltage is

$$E=Ri=-R\frac{dI}{dx}=2L\frac{x}{t}I \tag{110}$$

whereby E is reduced for every distance and time to equation 107 for the current I. Since E is proportional to I, a definite value of the impedance is obtained, which, however, is dependent on distance and time. The surge impedance is

$$Z=\frac{E}{I}=2L\frac{x}{t} \tag{111}$$

and is proportional to the self-inductance L per unit length of the wire. For any point x of the wire, Z is inversely proportional to time.

There may be correlated to the beginning of the steep ascent of the current with time, as shown by t_0 in Figure 28a, a location x_0 corresponding to about half the value of equation 108, so that

$$\frac{x_0^2}{t_0}=\frac{1}{4}\frac{R}{L} \tag{112}$$

By substitution of this value of x in equation 111 and use for R and L of values per unit length derived from equations 30 and 100 for a finite wire, the surge impedance for the terminal of the wire becomes

$$Z_0=\frac{t_0}{t}\sqrt{\frac{RL}{t_0}}=\frac{t_0}{t}\sqrt{\frac{2\rho\cdot10^{-7}}{\pi t_0}}\log_e\left(\frac{2l}{a}\right) \tag{113}$$

Since buried wires usually are embedded near the surface of the ground, extending to both sides from the terminal, the value of equation 30 is doubled for the resistance here in question.

We consider for an example a wire of length $l=75$ meters and of radius $a=0.5$ centimeter, buried in ground of high resistivity $\rho=10^3$ ohm-meter, and we estimate the time until the steep ascent of the lightning current occurs as $t_0=0.2\cdot10^{-6}$ second. Then the surge impedance for the practical start of the current at $t=t_0$ will be

$$Z_0=\sqrt{\frac{2\cdot10^3\cdot10^{-7}}{\pi\cdot0.2\cdot10^{-6}}}\log_e\left(\frac{2\cdot75}{0.5\cdot10^{-2}}\right)=184 \text{ ohms}$$

and this value decreases hyperbolically with increasing time as shown in Figure 28b.

The impedance would decrease gradually to zero, see equation 113, due to the omission of ohmic resistance of the infinite wire in this calculation. Actually the impedance cannot drop lower than the d-c ground resistance of the finite buried wire, which in this example is

$$R_0=\frac{10^3}{\pi\cdot75}\log_e(3\cdot10^4)=44 \text{ ohms}$$

thus limiting the decrease of Z, as shown in Figure 28b by the dashed line.

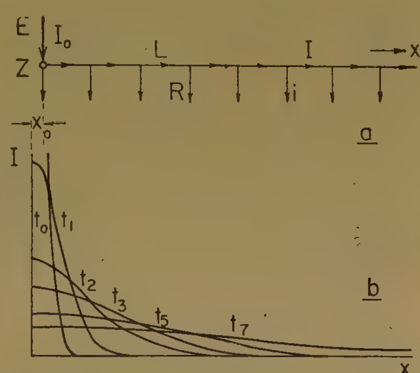


Figure 27. Distribution of impulse current along a buried wire

CONCLUSION

By using for the development of the current distribution in the ground such mathematical analyses as are best suited to each special problem, rather than any general method of rigorous calculation, the treatment does not depart far from the physical aspect, and the solutions become fairly simple and easy to survey, even in complicated examples. In view of the great heterogeneity of the ground under the surface of the earth, the effect of which can never be taken into account by any rigorous deduction, such a simplified foundation of the principles of ground currents appears appropriate from the viewpoint of engineering as well as from the viewpoint of the economic use of science.

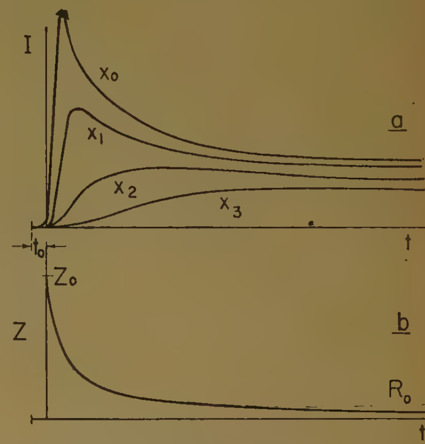


Figure 28. Change with time of current and surge impedance in buried wires

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The Engineer and His Future

C. A. POWEL
PRESIDENT AIEE

Representation of the engineer in civic and state affairs and promulgation of measures to improve his economic status by means of an overriding association of engineers are suggested by President Powel in this article.

WAR is a tremendous stimulant. It brings about not only enormous physical production, but also mental achievements, such as scientific inventions, art in the form of stirring posters, and literature in the form of moving books and articles dealing with various phases of the conflict. One result of this mental effort is a searching analysis of the position of the engineer in world affairs. It was evident during the last war and has come very much to the fore again during the last four or five years.

A frequent criticism is that the engineer does not carry enough weight in community and civic affairs and that he does not enjoy the public prestige and regard that his professional brothers in medicine and law enjoy. Another is that his occupation is not as continuous and secure as it should be. This is true particularly of civil and construction engineers. Another is that his remuneration is not as high as in other professions.

Whether these criticisms are well founded or not will remain pretty much a matter of opinion. It is impossible to establish the facts in the matter, because one can set up premises and definitions to prove one's case, just as in the present controversy regarding the increase in the cost of living one can prove anything from 10 to 100 per cent, depending upon what is included in the cost of living.

Nevertheless, because one cannot expect an exact answer may not be sufficient cause for ignoring the subject.

That the engineer in the early days did not get much public esteem is explained by the fact that most of them were essentially practical men with little theoretical training, whereas the physician, the lawyer, and the pastor were all university trained. The relatively few scientists who devoted themselves to technical developments never came in direct contact with the public, as did doctors and lawyers, and their work was consequently not appreciated outside of their own small circle. Up to the beginning of this century, theoretical training in an engineer was looked on by old timers with suspicion as likely to lead to errors in design and performance, particularly because the application of theory invariably led to marked savings in materials, which was tantamount, they argued, to removal of the margins of safety. The older professions likewise did not give the college-trained engineers a warm welcome, and attempted to establish a difference by referring to the "technical professions" as distinct from the "learned professions." The difference is real and engineers must recognize it. Today there is still no minimum standard requirement for the practice of engineering and even no satisfactory definition of what constitutes an engineer. In medicine, on the other hand, the minimum standard is not only well defined but also requires more than the bachelor's degree that satisfies most engineers. In law the situation is similar. While the general scheme of legal education differs in various localities and is not as uniform as in medicine, admission to the bar requires at least seven years of study.

However, criticism by the old die-hards did not retard progress of the theoretically trained engineer who became firmly entrenched in all branches of engineering to the exclusion of the rule-of-thumb type of man.

As the profession developed, more and more of these intellectuals began to realize that while scientific knowledge and engineering achievement were shaping the world and establishing the habits of thought and life, the engineer got scant recognition in the councils of government. Attempts were made to remedy this situation, notably by the establishment during the last war of Engineering Council. This association was formed under a broad charter of what is now the United Engineering Trustees to provide for closer co-operation among the four Founder Societies on matters of general interest to engineers and to the public, and to serve as an agency for united action upon questions of common concern to engineers.

In 1920 it was enlarged to include a much larger group of engineering societies and the name changed to Federated American Engineering Societies. A joint committee drafted the principles for a nationwide engineering organization to be composed of representatives of local, state, regional, and national societies. The conference met in Washington with 132 delegates representing 66 societies having a total membership of 130,000. After an intensive debate, a constitution was adopted containing the following objective: "To further the interests of the public through the use of technical knowledge and engineering experience, and to consider and act upon matters common to the engineering and allied technical professions."

In 1924 the name of the organization was changed to American Engineering Council and it functioned until the end of 1940 when it went out of existence due to lack of interest and lack of funds.

We need such an overriding engineering society as American Engineering Council that can speak for all engineers with some authority. Legislation of vital importance to industry is enacted but much of it shows no evidence that industry was ever consulted. Even the soundness of such a fundamental law as the Sherman antitrust law can be debated. Unrestricted competition does not necessarily produce the best results. We recognize this when dealing internationally by putting up tariff barriers to keep out those who can undersell us, but we close our eyes to it in our national affairs. In industries where the prices and wages are the same for all, those concerns are the most prosperous and successful that work with the highest efficiency.

Serious attacks are made on our patent system and on organized research for their alleged contribution to antisocial monopoly. Some of our socialist friends would have the product of organized research, both industrial and academic, become common property. In other words, they propose to kill the very thing that has put us in a leading position in scientific progress and has made possible our tremendous contribution to the winning of the war.

Tax policies and legislation are already such as to penalize thrift and make difficult financial protection against business recessions. These are all problems in which the engineer should interest himself because the engineer more than anyone else is shaping our present civilization. It was hoped that he would be able to express himself effectively through American Engineering Council, but that organization died for lack of support chiefly, I think, because it had insufficient contact with the rank and file of engineers, to most of whom it was totally unknown.

Engineering councils on a smaller scale are numerous throughout the United States in the form of local engineering organizations comprising all classes of engineers. Unlike American Engineering Council, they provide support of the engineering profession at the base of the pyramid, so to speak, instead of at the apex. They substitute a large cross-section of

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An address delivered at the AIEE Los Angeles technical meeting, Los Angeles, Calif., August 29–September 1, 1944.

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opinion for a small one. These councils should be encouraged, expanded, and also co-ordinated. They should include among their committees one made up of the most competent men in the district to follow legislation affecting industry and science to relay to the membership any steps by the governing bodies that adversely affect their interests. The individual members through letters to their representatives could then take appropriate action, if they so desired. The better these local associations are financed, the more effective they can become. One of the difficulties is that too many engineers fail to realize that the money they devote to such societies comes back to them many fold in benefits affecting the whole profession. Note the contrast of attitude in this regard between engineers and members of the big labor unions, whose individual incomes are probably lower but who, nevertheless, pay relatively high dues.

A more recent manifestation among engineers is a movement to band together in some form of collective bargaining to improve their personal fortune. Several reasons are advanced for this—one goes back to the depression of the early 30's when many engineers, capable as well as the incapable, could not find employment. This memory lingers and now that they have jobs and the future appears uncertain, they propose to set up machinery through collective bargaining to insure employment. A second reason is that under existing laws many engineers find themselves subject to more-or-less compulsory enlistment in labor unions not to their liking. So they would seek protection by creating an agency of their own. A third reason is the influence of arguments of the so-called white-collar unions that, while wage earners are getting fat pay envelopes through overtime payments and incentive bonuses and such schemes, salaries are fixed and can be improved only through collective bargaining.

None of these arguments can be dismissed as inconsequential. Certainly the young engineer is more practical as regards his personal affairs than were the engineers of past generations. We older men were much more lured by the romance of engineering. The joy of achievement, of new developments, of new solutions of all kinds of problems, were more important and gave us more satisfaction than a few dollars more or less in our pay envelope. Not until we thought of marrying did we discover we had no money. The romance of engineering is not dead, but neither is it any reason to discourage the practical attitude of the engineer. There is, however, a big question as to the best form of collective bargaining for the engineer. Should he form a union of his own or should he join one of the big labor unions organized for a totally different type of person with a totally different process of reasoning and a totally different function in society?

It may be entertaining and instructive to review the origin of those unions. The first union was no doubt founded by a few prehistoric men who discovered that their chances of remaining alive were much improved by banding together against their four-footed enemies. This type of union, of course, endured in the form of villages, cities, districts, countries, empires, and we hope, eventually will develop into one world-wide peaceful union of nations.

As men became skillful with their hands, another type of union, known as the guild, developed which had for its purpose the protection of artisans and other industrial classes. Guilds seem to have been formed first in China and India and introduced into Europe in the eighth century. The first English guilds were formed in the ninth century. These guilds were the forerunners of our technical societies and to some extent our modern labor unions. In the days of the guilds, the artisan was a capitalist to the extent that he owned the tools and other requirements of his trade. The introduction of machinery brought about the factory system with a large demand for capital and labor far beyond anything the guilds had had to deal with.

Labor laws go back in England for hundreds of years. Between 1345 and 1348 the great plague struck Europe, originating in Asia Minor and traveling west to reach England in 1348. The German historian Hecker estimates that 25 million people died, including nearly half the population of England. The result was a serious shortage of labor and wages went sky high. In 1351 to cope with this increase a law was passed known as the "Statute of Laborers" to fix wages and hours of labor at the pre-plague level. A section in the law was entitled "Victuals shall be sold at reasonable prices." In other words, it was an attempt to keep down the cost of living, which reminds us, of course, of our present Office of Price Administration. The workers did not accept this law without protest. One Walter Halderly in Suffolk was arrested because "he took eight pence a day at reaping time and at the same time made various congregations of laborers and counseled them not to take less than eight pence." He was the labor leader of his day and they put him in jail. But he had some success and after a time a union, or as they were originally called, a "combination," was formed known as the "Great Society," which forced some concessions from the king.

In 1562 labor succeeded in getting through Parliament a "Statute of Artificers" to curb employers who were cheating by paying only apprentice wages. The law forbade a man to employ more than three apprentices for each journeyman on his payroll, and is of interest as being probably the first law enacted with the idea of protecting labor. Most of the early laws were aimed to restrict labor and not to help it. Despite this, combinations of workmen were formed. Among them were silk weavers, basket makers, printers, shipwrights, shoemakers, carpenters, and bricklayers—names which are still familiar to us today. By strikes and by political means, these combinations kept on fighting for the betterment of conditions for the laboring classes, and finally, thanks principally to the efforts of a member of Parliament named Joseph Hume, they succeeded in 1824 in having a royal commission formed to investigate the whole situation. This resulted in 1825 in the repeal of all the previous statutes against combinations of workmen enacted during the preceding five centuries, and, a few years later, in the creation of the "Grand National Consolidated Trade Union," which was probably the first of the trade unions as we know them today. This huge combination of trades at its zenith comprised a million workers, an enormous membership for that period. However, because of internal strife, strikes, and lockouts, it finally broke up and in the middle of the century a fresh start was made with several smaller unions.

In Germany no unions exist. Trade unionism is possible only under a democratic form of government. Labor was always more government controlled in Germany than in other countries, but the revolution of 1918 did bring the German worker independence with collective bargaining and labor arbitration. The economic calamities, which may or may not have been purposely instigated, and the tendency of German labor toward communism, made possible the rise of Hitler. In May 1933 he ordered all unions abolished and their property seized. The union leaders were jailed. Labor was reformed into one government-controlled organization called the "German Labor Front" with Robert Ley as its head. To make it more palatable, employers and professional men were allowed to join. The organization was well dressed up, but the employer was the labor "leader" and the workmen were the "followers." The leader decided everything, but if there was too much complaining, there was recourse to "labor courts"—which meant the local Nazi "gauleiters."

The major purpose of the "labor front" was to inculcate the Nazi doctrine into the members. Even their recreation was supervised through a "strength through joy" department. As in Japan, the burden of government fell unduly hard on the worker and small farmer. In 1933 at the depth of depression the Nazis froze wages at their lowest level. The disparity between the incomes of the poor and the rich became greater in favor of the rich, which is rather an anomaly for a government calling itself "socialist." Another peculiarity of the Hitler brand of socialism, which is contrary to most socialistic ideas, is that he did not have much use for small corporations, which are difficult to control. Consequently, small corporations in 1934 were ordered to combine to a minimum capital of 500,000 marks. Any concern smaller

than this had to be a private business with the individual owner solely responsible.

The history of the labor movement in the United States is, as might be expected, different from that in other countries in view of its development. It was founded by men whose only gospel was free enterprise, even though they probably never had heard of the word. They came over here to better their lot and they had the courage to gamble. The goal was individual opportunity. The reward for taking risks had no limit. The greater the effort, the greater the reward. They found themselves in a country with tremendous opportunities and no labor. The first settlers were the Spanish conquistadores, a hardy crowd of toughs who came over for no other purpose than to spend the rest of their lives in luxury at the expense of the natives. They and their successors had a notorious aversion to work and they exploited the Central American Indians to the point where the Spanish Government had to step in for fear that this source of labor might be wiped out entirely. Incidentally, it is interesting to note that no one succeeded in enslaving the North American Indian. Our good Puritan forefathers in New England, having left Europe to enjoy freedom of thought, freedom of religion, freedom of action, did not indulge in slavery, but they were not above using indentured servants shipped over from England under some flimsy excuse of criminality or with no excuse at all. In 1670 a man and woman in England were fined one shilling each for kidnapping a young girl to ship over to New England. Had they each stolen a shilling they probably would have been hanged. Life was cheap.

In colonial days competition was keen for what labor was available. As far back as 1634 Massachusetts found it necessary to set up a board of three men in each town authorized to fix wages. The general idea was to keep wages down rather than boost them, but, nevertheless, it is interesting as being probably the first legal provision for arbitration in labor disputes.

However, a nation cannot remain forever made up of rugged individualists. Local opportunities decrease, the children and grandchildren are not so rugged, immigrants encouraged to come in as laborers are disillusioned, and the factory system inevitably establishes a class whose only recourse is the sale of their labor to others. These people were exploited just as in other countries—perhaps for a longer period because expanding frontiers and individual opportunities persisted much longer here than elsewhere and retarded collective action on the part of labor. There was also the added complication of diversity of action in individual states. And so, while America's first labor law was enacted in 1813, it was 100 years later that the World War I and the Clayton Act, exempting unions from the stipulations of the Sherman antitrust law, gave labor its opportunity of real development. The Wilson administration insisted that the war industries cease interfering with the organization of their employees and the first collective-bargaining agreement in this country was signed by Newton D. Baker, Secretary of War, and Samuel Gompers of the American Federation of Labor covering construction of camps and cantonments.

Labor unions are a necessary part of our economy. Looking over the picture as a whole, they have been beneficial. It is certain that without joint action on the part of labor our present standard of living could not have been attained. But the question properly may be raised whether the engineer belongs in the type of union just discussed? Does what he has to sell differ from what the machinist has to sell? There is certainly a difference. The machinist, the janitor, the shipping clerk, all have a set task previously laid out for them to do within the limits of their ability. The engineer on the other hand uses his intellect to do something new or different. His training has developed his creative instinct and he takes pride in accomplishment. His work has no monotony unless he wills it so, whereas a man operating an automatic screw machine has little opportunity for self-expression in his work. The engineer's work is not adapted to control by any ordinary time-study procedure nor are the scheduled hours of work likely to be rigidly adhered to. He is much more likely to become an individualist than a man working with a group in the shop. Nevertheless, the engineer has the same instincts of self-preservation as other people and it is natural that he should seek protection through some scheme of collective action. There is nothing wrong with the basic idea. There are all kinds of groups of professional people banded together for mutual assistance. But, how best to attain the desired result is something else again.

Two general schemes have been tried—one by the American Society of Civil Engineers which has authorized its sections to set up collective-bargaining units, and a second scheme prevalent in some plants where the engineers have simply been included in the general "white-collar" union.

In a few cases groups of engineers in a plant or on a project have been able to secure designation as collective-bargaining units; sometimes before a broad over-all unit has been certified, and sometimes breaking out of an already established and certified local bargaining unit.

I have been asked if the Institute should not adopt some such scheme as the civil engineers. The answer is that the Institute has a committee jointly with other technical societies to investigate the whole subject. I do not know what their report will bring forth, but I can state that their preliminary study brings out the difficulties of trying to make collective-bargaining units out of our Institute Sections.

The idea of including engineers in som general white-collar union at first glanc looks attractive but in practice it also ha its disadvantages. In any concern, n matter what size, the ratio of engineers t draftsmen, clerks, accountants, and s forth, is bound to be quite small, and on runs into the same comparisons as wit manual workers. The problems of th majority of clerks are much more aki those of the shopmen than those of the engi neer. The engineer, in my opinion, is jus as much out of place in the white-colla union as he would be in any shop union because he is subjected to decisions an rules that are clearly intended for a grea majority of men doing an entirely differen class of work.

Neither of these schemes, it seems to me is the answer to the problem if engineerin is to remain a profession and not degener ate into a trade. It is not enough to sa that belonging to a union for a time is useful part of a young man's training Most engineers never get into the super visory ranks and, therefore, would remai in the union for an indefinite period Moreover, the seniority processes of union are liable to be a handicap rather than a advantage to a young engineer's promotio apart from engendering a tendency to los initiative.

My present opinion, which may b changed later as the result of the finding and recommendations of the aforemen tioned committee, is that I question if bargaining agency in the ordinary sense o the term is necessary or desirable for engi neers and the protection they rightly see probably could be provided more effec tively by an overriding association em bracing all engineers, devoted specificall to the welfare of the profession as a whol and the individual members comprising it Such an overriding society by the weight o its opinion could help the individual i cases of gross injustice, which is the onl type of protection he needs. The types o grievances one encounters with labo unions are not ones likely to concern th engineer. The minor differences of opinio that arise in the course of his work are mor likely to be such that they can be settle directly with management.

An overriding association, such as th one suggested, must be entirely inde pendent of our technical societies whic have a very definite, important, and grow ing field of activity. It cannot be set up a a side line of the Founder Societies. I involves real money.

I believe our need is for some overridin association of engineers whose purpose i to represent all branches of the professio in civic and state affairs and which also i capable of watching over the welfare of it individual members in broad issues. I must first set up a definition of what consti tutes an engineer, and it must have constan and intimate contact with its local branche to keep the rank and file of engineers in formed and interested.

Lighting of Budd Field

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The indirect lighting by mercury-vapor lamps of a plant 25 acres in area and nearly 60 feet high is of interest to all illumination engineers. How a lighting system was designed which would meet the requirements from an engineering basis and at the same time be practical from a cost consideration is explained by two engineers who were concerned with the lighting of Budd Field.

THE BUDD ASSEMBLY PLANT at Bustleton, Pa., known as Budd Field, designed and built for the production of a cargo airplane fabricated of stainless steel, is constructed entirely of steel-reinforced concrete covering nearly 25 acres (Figure 1). The entire assembly area, nearly 600 feet wide and 1,800 feet long, is all on one floor. In plan the area consists of two sections each approximately 135 by 1,800 feet (designated high bays) and six sections each approximately 50 by 1,800 feet (designated low bays).

Each bay has a vaulted roof (Figure 3) made up of a compound curve which gives an appearance of a somewhat flattened section of a cylinder with a ceiling of smooth concrete. In the high bays the roof is supported by columns approximately seven feet by two feet six inches. In the low bays the supporting columns are two feet three inches by three feet. All columns are regularly spaced along the longitudinal element on 40-foot centers. Except for these supporting members there is almost no other structural interference in the entire building.

The vaulted ceilings have no beams or other obstructions with the exception of two rows of skylights in the large bays and one row of skylights in the small bays, together with suspension rods to support craneways and a monorail system throughout the entire plant. In the high bays, the maximum height to the zenith of the arch is 58 feet with a minimum mounting height for lighting equipment of 41 feet above floor level required for clearance of the conveyer systems. In the low bays the maximum height to the zenith of the arch is 33 feet with a minimum mounting height for lighting equipment of 23 feet six inches.

The illumination problem was to provide not less than 35 foot-candles and to design a lighting system which would meet the requirements from an engineering basis and at the same time be reasonable from a cost consideration. In attempting to solve the lighting problem the first subject reviewed was that of suitable light source. Of those commercially available the three which were given consideration were:

1. Incandescent.
2. Mercury.
3. Fluorescent.

An analysis was made of the pertinent data relating to each of the sources considered. It was logical that the high efficiencies of fluorescent and mercury-vapor lamps should gain favorable attention. The longer life of these two types of sources held real significance from a maintenance angle.

The question of relative color values was raised. Tests have shown that different color qualities of equal foot-candles of illumination have little effect on actual visibility. However, color does have a psychological effect that is worth considering. A light that is strong in blue or green is said to have a cool color, and many workers prefer it for certain visual tasks. Mercury lamps, or a combination of mercury and incandescent lamps, or fluorescent lamps produce such a cool quality. Sources strong in orange and red produce a warm color, the most common example being the filament lamp.

Fluorescent and mercury showed approximately equal merit on the basis of this preliminary analysis. However, the small amount of visible radiation from a single unit of the largest fluorescent lamp available indicated the necessity of installing tremendous numbers of them to produce the foot-candles desired. This suggested a considerable expenditure in maintenance costs. Such indications caused more and more interest in the mercury-vapor sources.

The high efficiency of mercury-vapor lamps merited particular attention. The then recently developed and newly announced 3,000-watt mercury lamp producing 120,000 lumens came in for much careful study. The high lumen output from a single light source was noteworthy from the standpoint of design because of the possibility of reducing the number of light sources required to provide the level of illumination desired. This naturally meant fewer light sources to be maintained.

Additionally, reported experience with smaller sizes of mercury-vapor lamps in other installations suggested the probability that with long hours of burning the useful life of the three-kilowatt lamp would be considerably more than its published life of 2,000 hours. This would add to its value from a maintenance angle. It was felt therefore that the possibilities of using this source should be investigated more carefully. Either alone or in combination with filament lamps, this new illuminant seemed to hold much promise for application design.

The apparent potentialities of the three-kilowatt mercury lamp were not all favorable. The intrinsic brightness of a source of such lumen output meant that a very serious glare problem might be presented. There was also the possibility of very uneven distribution and sharp shadows if a direct-lighting system using this lamp were to be installed. Lamp failures with

Figure 1. Artist's preliminary sketch of Budd Field

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ssential substance of a paper presented at the 37th nnual meeting of the Illuminating Engineering Society, hicago, Ill., September 14–16, 1944, and of an address efore the AIEE New York Section illumination group, ewark, N. J., October 10, 1944.

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he authors acknowledge the help of the Ballinger Company, consulting engineers; the H. B. Frazer Company, ectrical contractors; and the Philadelphia Electric ompany; who aided in the development of this installation.

a direct-lighting system might cause very low illumination levels in those areas where the outage of a three-kilowatt lamp occurred. These factors, plus the necessity of evaluating properly installations using the other considered sources, led to an analysis of suitable lighting systems.

Many layouts were made using the three types of lamps under consideration in almost every manner in which they could be applied. From these studies, five lighting systems finally were selected for further analysis. These five systems were

(*a*). Direct lighting using 1,500-watt incandescent lamps in porcelain-enameled steel high-bay reflectors on approximately 18-by-20-foot centers.

(*b*). Direct lighting using 400-watt mercury-vapor lamps in porcelain-enameled steel high-bay reflectors on approximately 13-by-13-foot centers.

(*c*). Direct lighting using a combination of 1,500-watt incandescent and 400-watt mercury-vapor lamps in twin porcelain-enameled steel high-bay reflectors on approximately 24-by-22-foot centers.

(*d*). Direct lighting using 100-watt daylight fluorescent lamps in two-lamp porcelain-enameled reflectors mounted in continuous strips on approximately 15-foot spacings.

(*e*). An indirect-lighting system using 3,000-watt mercury-vapor lamps.

Indirect lighting for an industrial plant on such a scale would be a novel experiment. While the many advantages had long been recognized, it had generally been conceded that an indirect system would be so far "out of line" on an economic basis that very few industrial applications had ever been made—particularly for such enormous areas with ceiling heights ranging up to almost 60 feet.

However, many features of this particular project substantiated the idea that a satisfactory and acceptable solution could be obtained with an indirect-lighting system. The curvature of the ceiling of the tunnel-like bays indicated the possibility

center position, the maximum-to-minimum ratio in distribution of light flux to the floor level was computed to be 1.25 to 1.

The 3,000-watt mercury-vapor lamp

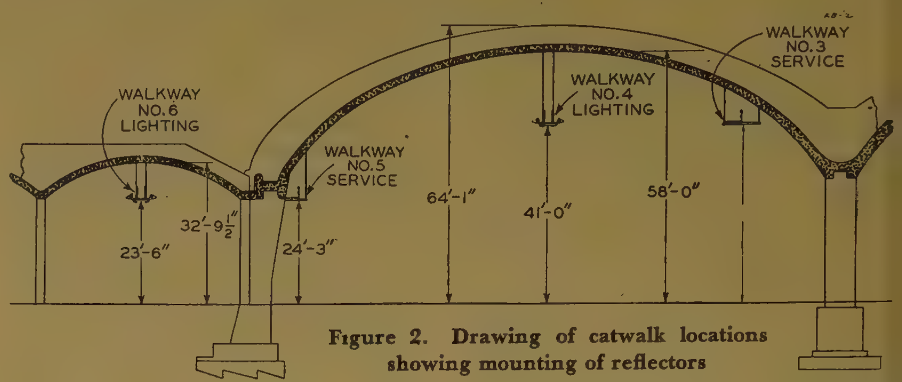

Figure 2. Drawing of catwalk locations showing mounting of reflectors

Fixtures are mounted on both sides of catwalks which are hung from the ceiling. Mounting height is approximately 41 feet in high bays and 23 1/2 feet in low bays

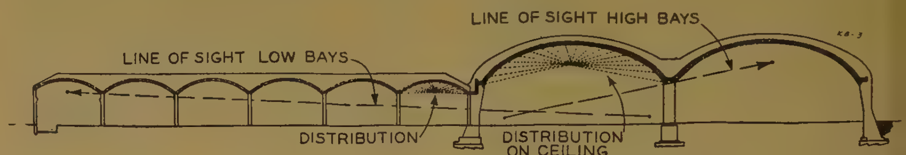

Figure 3. Cross section of building showing relative size of large and small bays and distribution of light on ceiling and shielding angle

Small bays are approximately 50 feet wide and 39 feet to the zenith of the arc; large bays are about 135 feet wide and 58 feet to the top of the arched ceiling

of using these ceilings as natural reflectors. If a light source of sufficient candlepower could be suspended from the zenith of the arch to approximately the mounting height already established by the limitations of the monorail system, the curvature of the ceiling would act as an integrator to produce almost even illumination throughout the working areas. From such a light-gave promise of meeting the existing requirements. It was therefore conceived that a continuous catwalk should be suspended from the center of the ceiling of each bay. In the large bays the catwalk would be suspended 17 feet from the zenith of the arch, thus providing the 41-foot clearance above floor level which was required. In the small bays the catwalks would be suspended the maximum of 9 1/2 feet from the zenith of the arch, providing the clearance of 23 feet 6 inches stipulated for this area. Thus, there was suspended from each arched ceiling a continuous catwalk 1,800 feet long or, in the total of eight catwalks some 2.7 miles of lighting system. On either side of these catwalks were to be mounted specially designed reflectors spaced at regular intervals (Figure 2).

Each reflector was to house a 3,000-watt mercury-vapor lamp, and it was to provide within the practical limitations of design an even distribution of flux on the arched ceiling. Additionally, care was to be employed in providing shielding from glare (Figure 3). The concrete ceiling was to be painted a matte white of not less than 80 per cent reflectivity. Furthermore, it was hoped that a white concrete floor could be provided.

A complete estimated cost analysis was made for each of the five systems previously selected. These analyses included the initial investment for luminaires and lamps, the cost of auxiliaries where required, th

Table I. Operation Characteristics of Light Sources

	Fluorescent	Incandescent	Mercury	Combination Incandescent and Mercury
Starting time	2–3 seconds delay Special ballasts—instant	Instant	Instant, but requires 3–5 minutes to reach full output	See components
Restarting after power interruption	2–3 seconds delay Special ballasts—instant	Instant	Requires 3–10 minutes to cool before arc re-establishes	See components
Rated average life (published data)	40 watts—2,500 hours 100 watts—3,000 hours	1,000 hours	400 watts—3,000 hours 3,000 watts—2,000 hours	See components
Removal after failure	Unless "no-blink" starter or instant ballasts are used, should be removed immediately	At convenience	At convenience	See components
Accessories required	Ballast transformer and starter	Self-contained	Ballast transformer	See components
Power factor	Correction to 95–99 per cent	100 per cent—no correction required	Correction to 95–98 per cent	See components
Sensitivity to voltage variation	See graph *A*	See graph *B*	See graph *C*	
List price	40 watts white —$0.95 40 watts daylight— 0.95 100 watts white — 2.15 100 watts daylight— 2.15	500 watts—$1.20 750 watts— 3.45 1,000 watts— 3.70 1,500 watts— 5.55	400 watts—$9.50 3,000 watts—40.00	See components

cost of installation; the cost of walkways where recommended; the cost of service trucks where suggested; the cost of painting where essential to the lighting system. Then, this initial investment for each system was amortized on a basis of eight years, five years, and three years. Additionally, the service costs were analyzed, establishing the kilowatt demand; the kilowatt-hours per year on 8,000, 5,000, and 3,000 hours burning; the annual energy cost on the same basis; the number and cost of lamp renewals; the man-hours for relamping and servicing of each unit; the actual maintenance cost of labor, and, additionally, the cost of repainting the interior of the plant where recommended as a specific requirement for lighting purposes. Thus, for each system, there was an estimate of the annual servicing cost

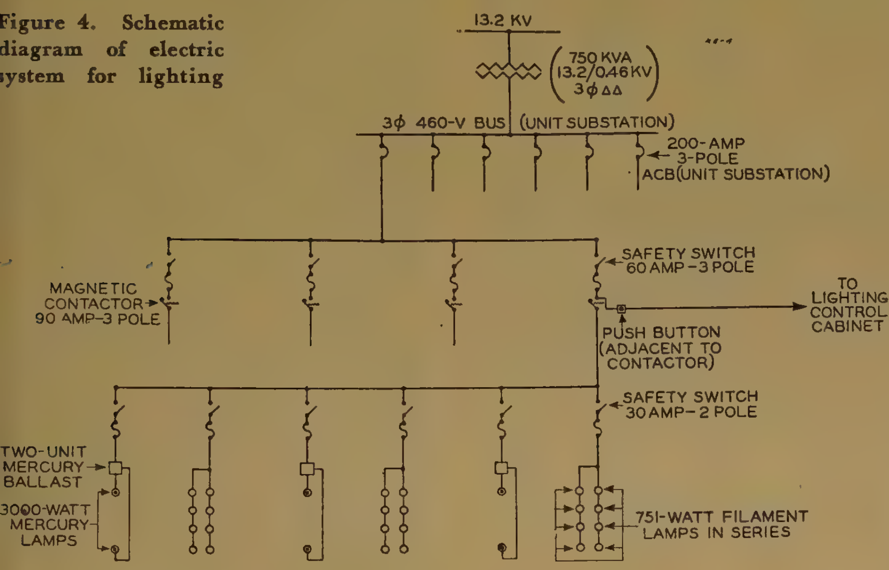

Figure 4. Schematic diagram of electric system for lighting

plus the annual capital charges. The result of these studies pointed to the probability that the totally indirect 3,000-watt mercury system could be justified on an economic basis.

In order to prove the practicability of such a system, a scale model was built. About six feet wide, three feet high, and approximately 30 feet long, the model represented one-third the full length of a high bay in 1/20th scale. To simulate the recommended lighting system, high-voltage fluorescent tubing with white cardboard reflectors was installed. The lumen output of the tubing was calculated to be within practical limits of the 1/20th scale of the model. It was anticipated that the results produced would give some approximation of the results which could be expected in the final installation. One change was made in the model; namely, solid walls were substituted for the open areas with supporting columns on 40-foot centers. However, it was estimated that the reflectivity obtained from these walls would not be in excess of the total flux contributed by the spill light from other bays when the entire system was in operation.

The entire interior of the model was painted with a white matte finish having an 88 per cent reflection factor. This, of course, was an ideal condition but was impractical because the floor would have to be painted to attain such efficiency. Illumination readings under these conditions averaged about 80 foot-candles at a normal working plane with a variation of less than 1.2 to 1 over the entire area. The next step was to paint the floor of the model with a matte paint of 65 per cent reflection factor. This reflectivity was equivalent to results attainable from a white cement floor. Illumination readings taken under these conditions produced an average of about 65 foot-candles with the same maintenance of distribution ratio. The third step was to paint the floor of the model a matte finish of 28 per cent reflection factor. This represented a reflectivity equivalent to results attainable from standard gray cement floors. Illumination readings under these conditions produced an average of about 45 foot-candles. Excellent uniformity in both horizontal and vertical foot-candles was found at various elevations above the floor level.

When these data were analyzed and the clean and cheerful appearance of the lighting system in the model was observed, it was resolved that a system of this type should be installed. Only one modification was made. Since considerable female help would be employed in this plant, and it was realized that the employees might object to the effect on their personal appearance of the blue-green predominance of a straight mercury-vapor installation, it was decided that an incandescent component should be added.

Electric service for the entire plant is furnished by the Philadelphia Electric Company at 66,000 volts and is stepped down at the main substation to 13,200 volts. Power is transmitted at this voltage through underground ducts to eight indoor substations in the assembly building.

Located at each of the eight substations is a 750-kva transformer for lighting service. Each transformer steps down the potential from 13.2 kv to 460 volts whence it is distributed by a three-phase bus through six 200-ampere three-pole air circuit breakers incorporated in a unit substation. From each air circuit breaker service is carried to a section of the catwalk where it is split into several lighting circuits. Each lighting circuit is protected by a 60-ampere three-pole safety switch and is remotely energized by a pilot circuit operating a 90-ampere three-pole magnetic contactor. Each lighting circuit feeds 12 lighting units which are electrically connected in pairs. A pair consists of two units of the same type, that is, either incandescent or mercury, located physically opposite each other on either side of the catwalk. The lead wires to a pair carry through a fused safety switch and thence directly to the units in the case of incandescent fixtures or through a two-lamp ballast and then to the reflectors in the case of the mercury fixtures. Switching control of pairs of reflectors or groups of reflectors on the catwalk permits isolation of units for servicing (Figure 4). Such safety measures made possible the use of 460-volt three-phase three-wire lighting-distribution circuits. Normal control of the lighting system is performed through the operation of push buttons in the lighting panels conveniently located throughout the plant. This operation energizes pilot circuits which activate the magnetic contactors which in turn control the groups of fixtures. This group control through the magnetic contactors is so arranged that selective sections of a continuous bay may be lighted or cut out if production schedules indicate the desirability of such procedure. The distribution wires are carried in a square duct laid on the floor of one side of the catwalk and, then directly to the fused safety switches controlling the pairs of mercury and incandescent units. A separate substation is provided to supply emergency lighting in case of failure of the normal incoming power lines.

Since this was a wartime project, in

Figure 5. View of catwalk from floor

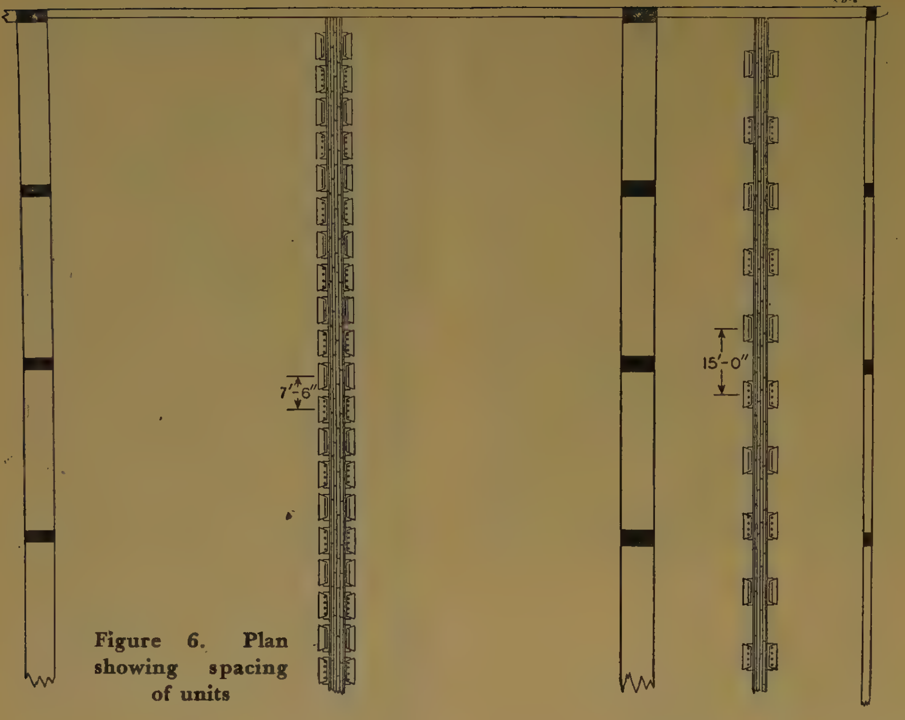

Figure 6. Plan showing spacing of units

addition to seeking the best possible illumination, it was necessary to give serious consideration to the conservation of critical materials. The indirect-lighting system as conceived was a step in this direction. The higher voltage and concentration of the lighting circuits produced drastic savings in copper. The relatively small number of fixtures needed to produce the desired quality of lighting also effected marked economies in the amount of critical materials used. A glazed-finish porcelain-enameled steel was selected for the reflector, a second choice to specular Alzak aluminum which was unavailable at that time because of war restrictions. However, the semispecularity of the glazed-porcelain enamel gave promise of producing satisfactory results.

The reflectors for both the mercury and incandescent lamps are very similar in appearance, particularly when viewed from the ground (Figure 5). Each unit is about 72 inches long, about 18 inches high, and 22 inches wide. Each mercury reflector holds one 3,000-watt lamp. Each incandescent reflector is equipped with four sockets so wired that 115-volt lamps burning in series operate directly on the 460-volt distribution system. The lamps are of the arc-resisting type which are so designed that on lamp failure the arc is quenched within the bulb. The sockets are mounted on adjustable supports, so that various lamp sizes can be properly positioned in the reflectors. In the high bays 751-watt lamps are used and in the low bays 501-watt lamps.

The reflectors are mounted on either side of the catwalks by means of a pair of bracket arms which are attached to the main channels of the catwalk structure. The reflectors are adjustable, and the brackets are equipped with stops so that

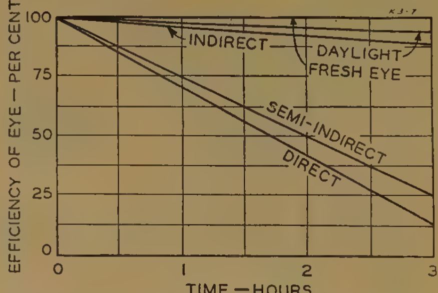

Figure 7. Ferree and Rand chart of eye efficiency under different systems of lighting after test period

the units can be tilted back to a servicing position and returned to their original setting. A clamp-type locking device also is incorporated. Along a catwalk the pairs are alternately filament and mercury. In the low bays the spacing between units is 15 feet, and in the high bays the spacing is $7^1/_2$ feet (Figure 6).

This lighting system is carried throughout the entire building with two exceptions. The assembly processes required a "dope room" which had to be isolated completely from the remainder of the plant and which necessitated the use of vapor-proof and explosion-proof lighting equipment. This dope room, 200 feet long and 100 feet wide, is a completely walled-in enclosure which breaks the continuity of the lighting system in two of the small bays. The second exception is in the low bay at the south side of the building. This bay is devoted to receiving and shipping, and approximately half of the floor area is taken up with sidings for freight cars. In this bay the catwalk was installed, but reflectors are mounted only on the north side of the catwalk. These two variations are the only exceptions in the continuity of the lighting system as described.

During the period of installation Government restrictions on materials became even more severe. As a result, the plan for a white concrete floor was abandoned. Also, paint manufacturers were deprived of certain ingredients needed for the ceiling that had been decided on; consequently, the finished ceiling, instead of having an anticipated minimum reflectivity of around 80 per cent, actually produced about 65 per cent.

At the time the plant was taken over by the Budd Company, an engineer was given complete responsibility for the lighting system. This engineer with his crew has been servicing the installation for nearly one year of operation. His records and reports provide the data which gave a clear-cut picture of the performance of this lighting installation.

The indirect lighting system proved to be by far the most economical from an initial investment standpoint. When wiring and installation costs were included the system proved to be the cheapest on the basis of first cost. Certain features of the building which in no wise affected the indirect system would have necessitated drastic changes in the other systems contemplated in the development stages.

The quality of illumination produced is all that could have been anticipated. To the observer the lighting on the ceiling is quite uniform, although in the small bays, because the catwalks are in fairly close proximity to the zenith of the arch and the light sources are on wider spacings, there is a slight variation in color caused by the alternate pairs of mercury and incandescent fixtures. However, this condition is not objectionable and, it may be added, is not particularly noticeable except to the critical observer. The ceiling brightness does not exceed 250 foot-lamberts. The distribution of light is excellent, producing a soft well-diffused illumination with a minimum of shadows.

The general appearance of the lighting system is functional and neat and produces an interior which is bright and cheerful.

When the installation first was put into service, illumination values were in the range of 45 to 50 foot-candles. The findings of Ferree and Rand (Figure 7) in their researches on eye efficiency under various systems of lighting indicated that indirect lighting could be given a much higher evaluation than other systems. Experiments in the plant showed that less foot-candles of indirect lighting would produce equal or better seeing conditions than a direct-lighting system of more foot-candles. This was proved in the few locations where local lighting was used. In spite of the fact that well-diffused low-brightness units were developed for the supplementary lighting the high specularity of stainless-steel surfaces made long-period seeing condition almost intolerable. Therefore it was believed that if 35 to 50 foot-candles of direct

lighting were considered adequate for war production, then a somewhat lower level of totally indirect lighting would provide at least equivalent and probably better seeing conditions. The first step was to introduce 120-volt incandescent lamps in place of the 115-volt lamps which were installed originally. This change obtained about 50 per cent longer average life for the filament sources while it also meant about 14 per cent reduction in the lumen output of these sources. It should be noted, however, that the incandescent component represents only one third of the total. Thus the loss in total lumens from this procedure was only about four per cent.

The three-kilowatt mercury-vapor lamp was such a recent development at the time the assembly plant was put into operation that few data on performance in the field were available. It was anticipated that under the operating conditions on this job the three-kilowatt lamp would have a life considerably in excess of its published rating of 2,000 hours, and that its efficiency would be fairly satisfactory throughout most of the operating period. The only way to determine the useful life in active service was to keep the three-kilowatt lamps in operation until failure occurred. Accurate records of ten months of service show that these sources have been operating on an average of 15 to 18 hours daily or a total of approximately 5,000 hours with only seven per cent replacements for the entire period. The available data also show that these lamps are producing about 75 per cent of their initial rated lumens output after the ten months of operation. The losses incurred in the execution of these procedures together with an estimated average depreciation of ten per cent in lumen output for the filament lamps result in a drop of approximately 23 per cent in resultant illumination values. On the basis of initial utilization, with no depreciation, this would mean an expectancy of about 36 foot-candles.

Of course, there has been a depreciation from the initial efficiency of the over-all system, which normally might be expected to reduce as much as 50 or 60 per cent. However, the assembly operations performed in Budd Field are particularly clean, and excellent housekeeping is required, especially in connection with the lighting system. The forethought in providing lighting catwalks makes maintenance easy, safe, and economical. Thus today the average illumination throughout the plant is approximately 30 foot-candles. This means a depreciation in utilization of about 20 per cent which for an indirect-lighting system, and particularly an indirect-lighting system in an industrial plant, is noteworthy.

It must be remembered that this lighting system is a new and somewhat radical design; that it was installed under the limitations of wartime conservation; that it is in the first year of its operation; and that, therefore, many experiments have been and are being made to determine acceptable illumination levels for the type of work, together with the most economic operating basis with all factors taken into consideration. Also, the efficiency of the light sources and the over-all system are both at low ebb. When relamping and repainting are put on a schedule where they do not occur at the same period, then maintained utilization will be higher. Postwar application of paint will result in better reflection factors, which also will improve utilization.

Sufficient information has been obtained from the Budd Field installation to warrant such consideration of future trends in industrial lighting. Here is a large-scale indirect-lighting installation where energy consumption is high, averaging approximately six watts per square foot. Lamp replacements for the incandescent component have increased maintenance costs. In spite of these factors, the annual cost of operation is considerably lower than the original figures, and the savings in production efficiency are enormous.

Table II. Annual Cost of Operation, Entire Plant—Three-Year Amortization

System	Large and Small Bays, 1,500-Watt Incandescent Lamp in High-Bay Reflector—Direct Lighting	Large and Small Bays, 400-Watt Mercury Lamp in High-Bay Reflector—Direct Lighting	Large and Small Bays, 1,500-Watt Incandescent and 400-Watt Mercury Lamps in Twin High-Bay Reflectors—Direct Lighting	Large and Small Bays, 100-Watt Fluorescent Lamp—Direct Lighting	Large and Small Bays, 3,000-Watt Mercury Lamp—Indirect Lighting
8,000 hours burning					
Equipment	$ 29,344.65	$ 81,296.24	$ 32,411.89	$ 204,161.60	$ 95,100.00
Energy	327,120.00	191,382.00	279,256.00	228,944.00	390,720.00
Lamp renewals	74,365.28	105,476.00	83,465.06	175,868.16	169,160.00
Maintenance	163,550.00	331,920.00	216,480.00	780,460.00	45,998.00
Total	$594,379.93	$710,074.24	$611,612.95	$1,389,433.76	$700,978.00
5,000 hours burning					
Equipment	$ 29,344.65	$ 81,296.42	$ 32,411.89	$ 204,161.60	$ 95,100.00
Energy	204,450.00	120,220.00	174,535.00	143,090.00	244,200.00
Lamp renewals	46,478.30	65,923.00	52,165.66	109,917.60	108,225.00
Maintenance	163,550.00	331,920.00	216,480.00	780,460.00	45,998.00
Total	$443,822.95	$599,359.42	$475,592.55	$1,337,629.20	$493,523.00
3,000 hours burning					
Equipment	$ 29,344.65	$ 81,296.24	$ 32,411.89	$ 204,161.60	$ 95,100.00
Energy	122,670.00	72,132.00	104,721.00	85,854.00	146,516.00
Lamp renewals	27,886.98	39,553.80	31,317.73	65,950.56	64,935.00
Maintenance	163,550.00	331,920.00	216,480.00	780,460.00	45,998.00
Total	$343,451.63	$524,902.04	$384,930.62	$1,136,426.16	$352,549.00

Figure 8. View of the Budd plant from the floor

Recent Electron-Tube Developments

S. B. INGRAM
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Electron tubes first were used in telephone systems chiefly for speech transmission; they now are being used extensively for many other purposes. A few specially developed amplifier tubes and some typical tubes used in the nontransmission part of the telephone plant are described in this article.

THE MAIN APPLICATIONS of electronics, at least until recent years, have been in the field of communication. Modern systems of radio and long-distance-telephone communication would be impossible without the electron tube. No alternative means generally have been available to perform the functions which the electron tube performs in the transmission of speech in communication systems and these functions were not performed at all until the electron tube came along. Of recent years electronics is receiving more extensive use in industry. The functions which the electronic devices are performing there are generally not new functions. They have been performed in the past by other means and the reason that the electron tube is being applied is that the electron tube can do an old function in a new and better way. A parallel development has been taking place in the telephone industry. For a long time although electronics was applied widely to telephony practically all the extensive uses had to do with the actual transmission of speech. Electron tubes now are beginning to play a much more important part in the operation of the nontransmission part of the telephone plant and are being used widely to perform the functions formerly performed by switches, relays, signaling devices, and rotating machines. This article attempts to survey, in a necessarily sketchy fashion, some of the recent applications of electron tubes to both the transmission and nontransmission parts of the telephone plant and to describe some of the tubes which have been developed for these uses. No attempt has been made at completeness and only the broad outlines of recent electronic developments in the telephone system are drawn.

TELEPHONE-REPEATER TUBES

In the transmission field recent long-distance telephone systems are largely of the carrier type where one pair of conductors carries more than one communication channel. The carrier systems are of three kinds, carrier on open wire, on small-gauge cable, and on coaxial cable. In many cases the first and second systems have been used to increase the capacity of wire facilities which already exist. By the addition of repeater stations at suitable intervals and of appropriate terminal equipment as many as 16 individual conversations can be transmitted over a single open-wire pair and as many as 12 over two pairs in conventional small-gauge telephone cables. In the coaxial system 480 telephone circuits may operate simultaneously over two coaxial pairs of conductors. Carrier systems of all types use as repeaters broad-band amplifiers of the negative-feedback type and have called for the development of special amplifier tubes to give the performance best adapted to the requirements of the over-all system.

In the design of tubes for broad-band amplifiers high transconductance and low input and output capacitance are desired. The maximum amplifier band width obtainable with a given tube is determined by a so-called "figure of merit" which may be defined as the ratio of the transconductance to the sum of the input and output capacitances. In practice, the figure of merit can be increased to its highest obtainable value only by using the smallest grid–cathode spacing it is possible to realize mechanically. Other desirable characteristics in tubes for telephone-repeater use are low filament-power consumption and long life. Long tube life is a factor of exceptional importance in all long-distance telephone systems. In the carrier systems particularly the maintenance of high quality of service requires that tube failures be reduced to a minimum because each tube is associated with a large number of circuits and each long-distance connection passes through a large number of tubes.

Figure 1 shows the 384*A* or 386*A* coaxial-cable amplifier tubes. These tubes are identical in appearance, differing only in internal structure. They are pentodes with small indirectly heated cathodes of one watt power consumption. A high transconductance has been obtained by the use of the indirectly heated cathode and a very small grid–cathode spacing, 0.004 inch. The figures of merit as defined hereinbefore are about 500 for the 384*A* and 725 for the 386*A*. When used as power output tubes in the coaxial system at 120 volts on the plate and working into 10,000 ohms impedance the 384*A* delivers 100 milliwatts and the 386*A* 25(milliwatts with harmonics 20 decibels o more down. With these tubes the lin amplifiers have a useful band width o three megacycles.

Figure 2 shows the 373*A* and 374*A* tubes the voltage- and power-amplifier tubes respectively, for the most recent carrier on-cable system. These tubes are pen todes with filamentary cathodes of $^{1}/_{2}$ anc $1^{1}/_{2}$ watts power consumption. The transconductances are 1,300 and 3,000 respectively, and the power output of the 374*A* is 1.3 watts with the second and thirc harmonics about 20 decibels down.

TUBES FOR RADIOTELEPHONE

The radio part of the telephone-com munication system is expanding rapidly Transoceanic and ship-to-shore radio play an important part in linking the entire world by one continuous interconnectec telephone network. The growth of wire carrier systems, as well as the increasing traffic on existing radiotelephone chan nels, has given an impetus to the study o multiplex radiotelephone systems capable of transmitting simultaneously a number o conversations associated with one carrie frequency. An interesting example is the 12-channel 160-megacycle system operat ing between Cape Charles and Norfolk Va. Here a 26-mile radio link across the mouth of Chesapeake Bay carries traffic which otherwise would have to be routec around the bay by way of Baltimore anc Washington, a distance of 450 miles. The system is capable of accepting and de livering the 12 channels of the standarc type *K* carrier-on-cable system which lie in the 12- to 60-kilocycle band.

Multiplex radio systems place much more severe requirements on the fidelity of the radio transmitter and receiver than

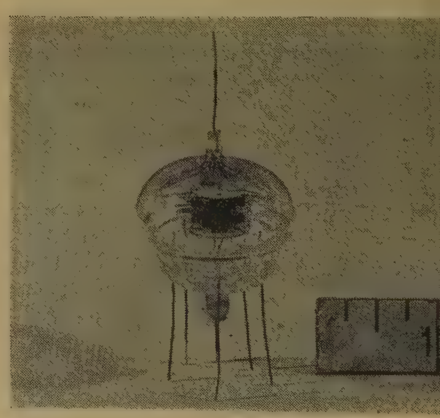

Figure 1. Coaxial-cable-amplifier tube 384A or 386A, which differ only in in ternal element structure

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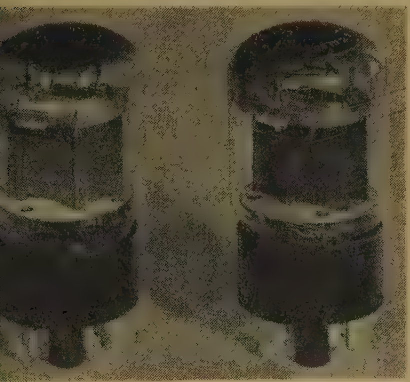
e commonly met with in single-channel
nsmission. This fidelity is necessary to oid intermodulation between channels. obtain this high degree of fidelity, ile still maintaining efficiency by using nal amplitudes comparable with the ted output of the tubes in the final stage, gative feedback has been employed. e circuit problems of this system are mplex, and their solution would have oved much more difficult without the roduction of several new tubes specially signed for this system. The novel fea-res of these tubes will be useful in other plications.

The output stage of the Cape Charles stem consists of a pair of 50-watt triodes erated push-pull in a bridge neutralized cuit, plate modulated by a 350-watt ntode. The triodes, known as 364*A* bes, are a redesign of the older 356*A* be. Both tubes are shown for comparison Figure 3. The improvements, all con-buting to improved performance at the gh frequencies, are decrease of the transit ne by use of smaller grid–filament spac-g, shortening of all electrode leads to duce their inductance, and the bringing t of duplicate plate and grid leads rough the glass envelope. The first and t of these features, particularly, are of portance in the design of the multiplex cuit. This is because phase modulation the output results in distortion and erefore intermodulation between chan-ls, and phase modulation can arise her from variation of transit time with odulating voltage or from the presence any impedance common to the input d neutralizing circuits.

The 350-watt pentode is used in the pe Charles system to plate modulate the 4*A* tubes because it is capable of deliver-g 65 watts of audio-frequency power at 50 volts to the 7,000 ohm impedance esented by the two triodes, with distor-n less than that contributed by the odulated stage itself. No other avail-le tube is capable of this performance. hile the tube is used here in class *A* eration at carrier frequencies up to only kilocycles, its possibilities are perhaps st interesting in the ultrahigh-frequency field. It is designed with short electrode leads of low inductance and is capable of operating at full ratings up to 85 megacycles. Thorough shielding reduces the grid–plate capacitance to 0.06 micromicrofarad. This shielding includes a plane shield at suppressor-grid potential, running laterally across the tube to the glass walls, and designed for extension outside the envelope by the circuit shielding. The transconductance of the tube is 12,000 micromhos, and the input and output capacitances are 29 and 21 micromicrofarads, respectively. The tube has a 100-watt thoriated-tungsten filament. It is known as the 363*A* and s illustrated in Figure 4.



ure 2. Amplifier tubes for carrier on cable system

—373A (*B*)—374A

THYRATRONS FOR BATTERY CHARGING

Every telephone central office has a reserve power supply to assure continuity of service when the primary power supply is interrupted. This reserve is generally a storage battery. The charging of the largest of these batteries in power plants where the drain may run to hundreds of amperes is done most economically by motor generators. Formerly the chargers used in the smaller power plants were of the same kind used in garages, that is, manually controlled rectifiers of the so-called Tungar type. During the last ten years, these have been rapidly replaced by regulated rectifiers using thyratron tubes.[1] A number of advantages in operation and maintenance are gained by the use of this modern equipment. The regulated rectifiers maintain the battery terminal voltage at a constant value, independent of variations in load and line voltage. Fluctuations in current drain automatically are taken care of by variations in the output of the rectifier so that, under normal circumstances, the battery is maintained in a stand-by floating condition. This greatly increases battery life and has the added system advantage that the direct voltage is maintained approximately constant instead of fluctuating over wide limits during the cycle of charge and discharge.

Three-element thyratron tubes have been used in these regulated rectifiers. An innovation has been to fill the tubes with a mixture of mercury vapor and argon at a pressure of approximately 100 microns.[2] Thyratrons have commonly been made with either mercury-vapor or rare-gas fillings. Mercury-vapor tubes are desirable because of their long operating life and low tube drop which permits high circuit efficiency. They have one undesirable feature, the dependence of their grid characteristic on temperature and their inability to operate satisfactorily at low ambient temperatures. Rare-gas-filled tubes, while lacking the latter limitations, are not yet available with life expectancies of greater than a few thousand hours. The gas-mixture tubes combine the advantages of both types, possessing temperature stability and at the same time maintaining a low drop throughout a long

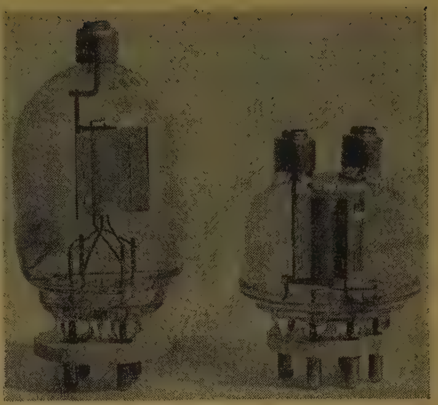


Figure 3. Fifty-watt triodes

(*A*)—*356A* (*B*)—*364A—output tube for Cape Charles transmitter*

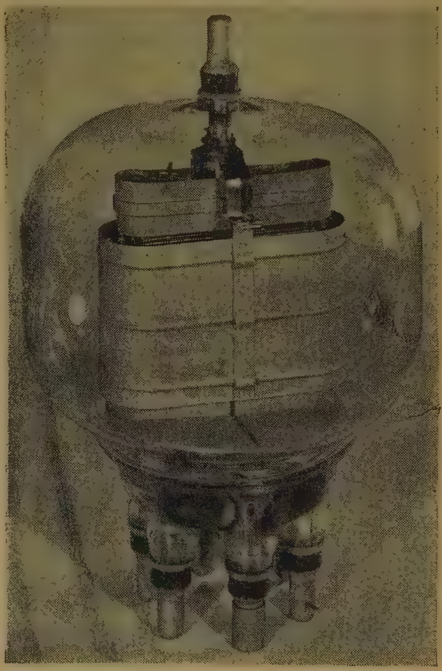


Figure 4. Type 363A 350-watt ultrahigh-frequency pentode used as modulator in Cape Charles transmitter

service life, 10,000 to 20,000 hours in typical telephone service. The earlier tubes of this type were limited in their inverse voltage rating to about 500 volts because of the presence of the 100-micron pressure of argon. Increase of this rating by the reduction of gas pressure was found to be impossible without running into danger of gas cleanup, but a modification in the tube geometry in which the grid and anode structure are closely inserted into the confined space of the dome of the glass envelope gave substantial improvement. This so restricted the length of electron paths in the grid–anode region where the high fields occur that such tubes are capable of withstanding considerably higher voltages than the earlier unshielded tubes. The most recently developed tubes of this type are rated in inverse voltage as high as 1,250 volts and can be used in single-phase regulated rectifiers with d-c outputs

up to 350 volts. Figure 5 shows one of the older designs, a Western Electric 323*A* tube, compared with the newer 393*A*, which is the same in its characteristics except for the higher inverse-voltage rating. These tubes are rated at 1.25 amperes average anode current. The 394*A*, a smaller tube with half the filament power and anode current rating, is also shown.

COLD-CATHODE TUBES

Cold-cathode gas-filled tubes have found extensive application in the telephone plant.[3] Since they require no filament power, they are admirably adapted for the intermittent type of service frequently encountered in telephone equipment. Fundamentally, small thyratrons could be used in most places where cold-cathode tubes have been applied, but the filament-power consumption would be prohibitively costly. In some cases, for example in subscriber-station equipment, local filament battery would have to be installed making their use on any extensive scale quite impractical. Furthermore, all thermionic tubes have a relatively short life expressed in terms of years even when operating in stand-by service with no plate current flowing. Cold-cathode tubes, by contrast, when operated on light duty will supply many years of trouble-free service without replacement. In many places in the telephone plant such tubes are soldered in place because they are not considered to be replaceable items.

The use of cold-cathode tubes for four-party selective ringing in which the tube is used as a rectifier in series with the subscriber's ringer to discriminate between positive and negative polarity of ringing voltage has been described previously[4] and is no longer new. It is important because of its extensive use running to hundreds of thousands of such installations. The tubes used, the Western Electric 313*C*, 333*A*, and 372*A*, which differ only in basing arrangement have also been described before. Figure 6 shows the structure of the 313*C* tube and compares it with that of the 359*A*, a more recent development. This latter tube is one with about the same characteristics as the 313*C* but much smaller in size and rated at about one half of the current. The economy in size is obtained by the compact internal arrangement of the elements. The cathode is a coated nickel cylinder, crimped at the top and supported from the glass wall by molybdenum springs. The control anode is a small nickel wire spaced but a small distance from the cap which closes the lower end of the cylinder. The anode is a wire extending through a mica disk which rests directly on the top of the glass press and shields it from deposits of getter material, cathode coating, or other substances which might cause electrical leak between the elements. Breakdown between the leads is prevented by glass sleeves which are not sealed to the press, but extend through the mica shield.

Figure 5. Thyratrons used in regulated rectifiers for battery charging in telephone central offices

(*A*)—323*A* (*B*)—393*A* (*C*)—394*A*

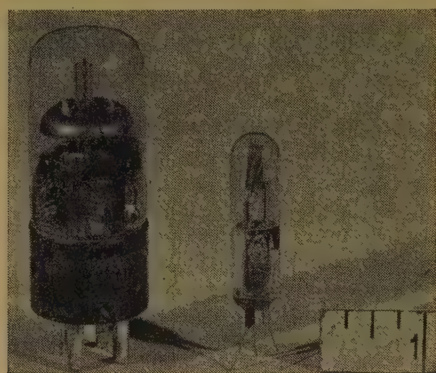


Figure 6. Cold-cathode tubes used in the telephone plant

(*A*)—313*C* (*B*)—359*A*

Extreme mechanical ruggedness is a feature of the design.

The principal application of this tube to date is in a small secretarial board at which an attendant can pick up any one of 10 or 20 subscriber's lines.[5] A tube is associated with each line and is operated by a ringing voltage coming over the line from the central office. An audible ringer is placed in the lead common to the anodes of all the tubes to attract the attention of the attendant if absent from her desk when a call is received. The correct called line can then be identified by noting which tube lights. The tube thus serves the dual purpose of relay and visual signal.

Another extensive application of cold-cathode tubes, interesting because of the nature of the function which the tube performs and important because of the number of tubes involved, is a registration system for use in large metropolitan areas. Central-office battery is commonly 48 volts. This voltage is insufficient to break down a cold-cathode tube so the tube may be placed between the line and ground without introducing transmission loss or noise into the talking circuit. The system provides that when the operation of the registration feature is required higher-voltage pulses simplexed over the loop from a tandem office to the central office break down the tube and operate a relay in its anode circuit. It thus operates as a relay which has infinite impedance to the voltages ordinarily encountered during conversation. In the largest application of the arrangement which is in New York, N. Y., approximately 50,000 tubes are installed. The tube used, the 346*B*, is similar to the 313 type, but has a longer cathode–anode spacing and a higher argon concentration to give it the higher main-gap breakdown voltage required by the application.

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2. Thyratrons for Grid-Controlled Rectifier Service, **G. H. Rockwood.** Electrochemical Society *Transactions*, volume 72, 1937, pages 213–23.

3. Cold-Cathode Gas-Filled Tubes as Circuit Elements, **S. B. Ingram.** AIEE *Transactions*, volume 58, 1939, July section, pages 342–7.

4. Vacuum Tube Improves Selective Ringing. **L. J. Stacy.** *Bell Laboratories Record*, December 1936, pages 111–13.

5. Secretarial Key Equipment Using Neon Signals, *Bell Laboratories Record*, July 1941, page 354.

High Soldering Temperatures Destroy Wire

That temperatures and operation times commonly used in soldering copper wire reduce wire diameter, decrease its life, and even totally destroy it, was discovered by the engineers of the Fairchild Camera and Instrument Corporation during an investigation of a single-step hot-tin-strip method of stripping and tinning copper wire.

Tests disclosed that with increased working temperatures and tin content of the solder went greater likelihood of wire destruction. Reduction in operating time attendant upon higher temperatures was not sufficient to forestall destruction of very fine wires. Unfortunately also, an all-lead solder results in a considerably weaker joint than a tin–lead solder.

Destruction of the copper is believed to be an alloying away of the copper largely by the tin in the solder. The wire embrittlement occurring at high temperatures is caused by a subsurface coarsening of the copper crystals and the formation of a hard foreign substance between the solder and the copper zones.

The data indicate that on wire sizes finer than approximately number 30 or 32 wire, temperatures for tinning and making joints should be kept under 600 degrees Fahrenheit and that a 40 per cent tin, 60 per cent lead, solder should be used.

IX—Research–Creator of Employment

A. W. HULL

In this article a physicist offers his views on how research can promote progress and ameliorate unemployment rather than an engineering analysis of what present methods and machines lack. The developments recommended are not mere revisions of existing techniques but sign-posts to untried paths.

SEVERAL new factors call for increased industrial research after the war.)ne is a growing belief that research pays. .nother is the force of public opinion, 'hich is becoming research conscious, so ıat customers and stockholders will give reference to those companies which have ctive research programs. A third new ıctor is the threat of government action. overnment will step in to satisfy the pub-c demand for research, if industry fails › do so. Certain types of fundamental search are proper government activities, ut other types, especially the later de-elopment stages of research, cannot be parated from responsibility for produc-on. Many believe that government ıould not enter this field.

The most important reason for increased search, however, is its effect on employ-ıent. It generally is agreed that our umber-one enemy after the war will be nemployment—not the temporary dis-ıcation of reconversion but the malignant isease. The battle against it will be long nd difficult, and we shall need new weap-ns. One of the most effective of these is search.

In the past, research has helped combat nemployment by developing new prod-cts and more efficient methods, which imulated business. Its most important ervice, however, is yet to come, and the apidly growing appreciation of research ives promise that it will come. That ervice is to keep alive the spirit of progress nd adventure which made our country rosperous in the past and can continue to ıake it more and more prosperous in the ıture. Will the fountains of prosperity ecome exhausted? Every scientist would nswer "No; we have scarcely scratched ıe surface of scientific exploration."

PROGRESS VERSUS INERTIA

Unemployment goes with a static econ-my, which human beings, particularly mericans, detest. We are happy only hen we are progressing. Inertia is in-lerable. In this we are like children building with blocks. The child's hap-piness changes to gloom when the last block has been placed on his castle. He is unhappy because, like Alexander the Great, he can see no more worlds to con-quer. It was not the castle which he wanted, but the pleasure of building it. So with the American people, it is the process of getting rich that gives them pleasure, not the wealth. If evidence of this truth be needed, it may be found in the lack of correlation between wealth and happiness. One does not observe that the rich people are the happiest ones, the middle class less happy, and the poor people unhappy. But one doesobserve that those who are progressing are, as a rule, happy, and those who cannot progress are unhappy. The workman is not satisfied to have his wages high. He wishes to see them increase. The farmer must see his net income grow each year. Business and industry must be expanding to be healthy. Can this expansion continue forever with-out reaching saturation? Science says yes. Research can provide new products and new methods of production that will keep our scale of living increasing and our economy expanding without limit.

But something more than the *fact* of progress is needed to combat depression and unemployment. There must be a *spirit* of progress, an atmosphere of un-limited horizons and unbounded oppor-tunities, an atmosphere in which fear and defeatism with their offspring of unem-ployment and want in the midst of plenty, cannot thrive. I believe that scientific re-search, if sufficiently active, is capable of producing and maintaining this atmos-phere.

MORE RESEARCH IS NEEDED

The attainment of this atmosphere of progress and adventure requires a tre-mendous expansion of research and means a greater expenditure for research in the future than in the past. Can our economy stand such an expenditure? In 1937 the total expenditure for research in the United States[1] was 0.29 per cent of the total national income and 0.64 per cent of the value of the products affected by the re-search. For the electrical industry the average expenditure was 1.67 per cent of such value, which in this case is the same as gross income. These are large expen-ditures, but they are small compared to the cost of unemployment. For example, as a result of unemployment the average national income for the ten-year period, 1930–1939, fell short of its 1929 full-em-ployment level by 30 per cent.[2] This loss from unemployment is more than 100 times the total amount spent for research during the same period.

The difference between 0.29 per cent and 30 per cent indicates that the country could afford to spend a much larger frac-tion of its national income for research, if such expenditure would eliminate unem-ployment loss or considerably reduce it. Even the 1.67 per cent spent by the elec-trical industry is small compared to 30 per cent. If research is a good method of combating unemployment, the electrical industry certainly would be justified in doubling its research effort. The limit which such expenditure might reach profitably may be much higher but does not have to be determined at this time, for the rate of research expansion is necessarily slow, being limited by the rate at which qualified research men can be trained.

INDUSTRY CANNOT AFFORD NOT TO DO MORE RESEARCH

Who will pay for this research? Can industry afford to pay for it? The answer

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is that industry cannot afford not to. A list of the profitable lines in the electrical industry shows that a large fraction of them were not in existence 25 years ago: Electric refrigerators; the whole electronic industry, including radio, electronic industrial control, and presently television; mercury turbines; fluorescent lamps; Pyranol capacitors; Spiracore transformers; Alnico magnets, oil-immersed X-ray tubes, Amplidynes, superchargers—the list might be prolonged. If we have courts which are just enough to allow a reasonable equity in products such as those mentioned to the companies which develop them by their research, then the latter companies will be the ones which will stay in business, and those companies which spend nothing for research will lose out.

PROBLEMS AWAITING RESEARCH

Some of the problems which await research can be enumerated, though they are not necessarily the most important ones. In the past the most valuable results of research have been unexpected developments that could not be foreseen. Such discoveries, however, generally are made while working on other problems of the day. So immediate objectives can serve as starting points for fundamental research, in addition to solving practical projects. The following suggestions are the views of a physicist regarding what can be done and not an engineering analysis of what is needed. These things are not needed from the operational standpoint; our present systems work well. They are needed for progress, in order to make the present systems obsolete.

Generation of Electric Power. It was believed 20 years ago that the large steam turbines, developed during the first World War and perfected in the five years following, represented a close approach to the ultimate in generating efficiency. Since that time the efficiency of steam turbogenerators, in kilowatt-hours per pound of coal, has nearly doubled, thanks largely to metallurgical research; and the mercury turbine has added another 14 per cent. Is this then the ultimate? No, it now appears possible that a still further advance can be made by the gas turbine, a promising project for research. The gas turbine will need steel which is still stronger at high temperature. Thus research in metallurgy is a necessary part of electrical engineering.

The use of higher frequency for the generated power can reduce the weight of generators, transformers, and motors. This demands further research on low-loss transformer steel, another metallurgical problem. Experimentation on the use of higher frequency in power systems can be facilitated by the use of d-c transmission links between the generating stations and the power systems which they feed. This calls for electronic research on the conversion of alternating current to direct current and vice versa.

More important than improvement in turbogenerators is research on water-power generation of electricity, in view of our limited coal supply. I am not one of those who worries about what future generations will do—they will wish to have the pleasure of solving their own problems. But nobody likes waste, and the use of limited coal in place of unlimited water is waste, providing both cost the same. Research on water-power generation and transmission of electric energy can enable it to compete with generation from coal. The electrical industry should cease looking upon water-power generators as stepchildren, and give them the benefit of greatly increased research effort.

Underground Power Transmission. The desirability of putting electric power lines under the ground is unquestioned. Since there is no immediate need for it, however, research in this direction can be justified only on the basis of safety, or esthetic value, or of eventual cost reduction. Underground transmission looks like a good bet from the cost standpoint. Two recent economic changes are in its favor, namely, the increased cost of labor, which demands troubleproof installations, and the decreased cost of money, which justifies larger investment in permanent equipment. Many research problems are involved. One of the most important is a cable-covering material which is resistant to abrasion and immune to electrolysis and bacterial decay. Plastic materials answering these specifications are almost in sight. That is a problem in chemical research. Another problem is the study of incipient corona in cables, which eventually breaks down the insulation. Or does it, if the insulation and gases are of the right composition? What is the mechanism of breakdown of solid insulation?

Ten years ago it was estimated that 500 miles was the maximum practical distance for d-c power transmission. Today the decrease in the cost of money would justify twice as great an investment in copper; for example, a cable of the same size but twice as long. Its resistance would be twice as great, hence only 70 per cent as much power could be sent over it at the same power loss. But, if the cable were improved by research so that it would stand 40 per cent more voltage, then 100 per cent power could be sent over it for the same power loss. This would make the 1,000-mile cable of tomorrow as efficient and as economical in cost as the 500-mile cable of ten years ago.

One of the most interesting features of power-transmission research is its electronic component. This will be of increasing importance. Whether the underground transmission utilizes alternating current which is stabilized electronically, or uses direct current, rectified at the generating end and inverted back to alternating current at the receiving end, electronic tubes and electronic research will be needed. Thyratron tubes will be required which can control at least 200 amperes at 20,00[illegible] volts, and have a life expectancy of 10 to [illegible] years. Such tubes have been produced [illegible] the laboratory, and their commercial de[illegible]velopment awaits only applications.

Research on such underground electri[illegible] power transmission can be carried out [illegible] a small scale without the necessity of [illegible] decision on whether an a-c system or d-[illegible] system shall be used. This is possible be[illegible]cause the transmission link, especially if [illegible] is a d-c link, can be inserted in eithe[illegible] system without disturbing it. Even if th[illegible] research involves a constant-current d-[illegible] link, which gives minimum cost of elec[illegible]tronic equipment, there is no effect on th[illegible] system, the power being transformed fro[illegible] the alternating constant voltage of th[illegible] power system to direct constant current [illegible] one end, and back again at the other en[illegible] This makes research at moderate cost pos[illegible]sible.

Electric Refrigeration. One frequentl[illegible] hears, "Washington would be a fine plac[illegible] to live, if the summers were not so in[illegible]tolerably hot, especially the nights." Similarly, "My chief memory of Englis[illegible] universities is the freezing lecture halls." The conditions underlying these state[illegible]ments are the same. The English conside[illegible] central heating a luxury; we hold the sam[illegible] opinion about cooling. We view the ex[illegible]penditure of $100 to $200 per year for hea[illegible] as a necessity, but recoil from the idea of [illegible] comparable expenditure in order to becom[illegible]fortable in summer. Although these atti[illegible]tudes are matters of mass psychology, the[illegible] are influenced by the availability and co[illegible] of equipment. It is a safe guess that hom[illegible] cooling will become common in th[illegible] country when sufficiently good and chea[illegible] coolers are available. Thus there is a[illegible] excellent field for research in home coolin[illegible] refrigeration equipment. Foremost is th[illegible] question of the cost of equipment, whic[illegible] must be reduced by research; but man[illegible] other problems for research are involve[illegible] such as noiseless blowers, humidity con[illegible]trol, moisture proof walls, and hermeti[illegible] double windows. The problem of usin[illegible] refrigeration equipment for heating at a[illegible] efficiency of 400 per cent or higher is [illegible] fascinating one, and a single unit for hea[illegible]ing and cooling should be practical fo[illegible] moderate climates, where the heating an[illegible] cooling loads are of the order of four [illegible] one.

Home cooling involves the whole prob[illegible]lem of home building, since, like centr[illegible] heating, it must be built in and requir[illegible] special construction. This home proble[illegible] is one of the most important fields of pos[illegible]war research. The electrical industr[illegible] should have a large part in this researc[illegible] since it now supplies much of the built-[illegible] comfort of the home, and can supp[illegible] still more with research. For exampl[illegible] dust, a major enemy of every good hous[illegible]keeper, can and should be kept out [illegible] the same means which exclude cold a[illegible] heat and water vapor.

Refrigeration of food is destined to pl[illegible]

a much larger role in the future. With domestic service scarce or nonexistent and a larger fraction of women in factory and office jobs, factory-prepared food will be in greater demand. It is safe to say that we have scarcely scratched the surface of the problem of preparing and preserving food. Much more research is needed on new methods and new containers, on high-frequency electric cooking, and on vacuum dehydration. Especially there is need for fundamental research on the physical and chemical changes that accompany freezing, heating, and drying.

Electronics. Electronics was old yesterday, with radio approaching saturation. Today it is new, with a large and interesting future before it. New devices and new attitudes have wrought the change.

Television is imminent, but requires much more research before it is entirely acceptable and then still more in the never-ending pursuit of perfection. Better camera tubes, larger pictures, more perfect synchronization, and simpler and cheaper circuits are obvious objectives. An extension of the frequency range, which will be possible with war-developed tubes, will provide sufficient band width for frequency modulation of the video signals, if this be found desirable. Present methods of frequency modulation cannot be used at these high frequencies, and new ones must be found by research. There also will be room enough for color television, which will be a research problem for a long time. It can be produced by mechanical scanning, but surely there is a better way.

Electronic industrial control is especially deserving of research, because it is one of the most effective weapons for fighting unemployment. At first sight it appears just the opposite; a device which enables one man to do the work of two would throw half of the men working out of work. this would be true, if the new device were introduced suddenly and if the amount of work were limited. But it cannot be introduced suddenly, because such devices require time and experience and research for their introduction; and the amount of work in the world is infinite, being limited only by human wants, which are insatiable. It generally happens that an improvement which cuts the labor and, hence, the cost of an article in half, multiplies the demand by at least four, so that twice as many men are needed for production, and not half as many. The opportunities for electronic control of industrial processes are unlimited, and the research opportunities include new electronic devices, new types of motors with instantaneous speed and torque response, and new automatic processes for a wide variety of industries.

Higher and higher in the electronic frequency spectrum lies the alluring pioneer frontier of electronics. Some valuable products in this region have been discovered during the war, of which the most important is radio echo-location of objects. Research will be needed to adapt this war weapon to furnish eyes for airplanes. What lies beyond? Perhaps meteorological observations, with waves which are reflected from clouds and raindrops, or absorbed by water vapor are the next advance. This would give us an additional instrument for the study of weather, the number one problem in air travel and in farming. Higher still in frequency lie the means for study of chemical bonds with waves whose frequencies are the same as the natural oscillations of molecules. These objectives are the treasures which we shall seek, which will serve as justification for the adventure. We shall, if fortunate, discover something much greater.

Atomic Energy. Shortly before the war it was discovered that certain atomic nucleuses become unstable when struck by neutrons and in exploding release an amount of energy greater than that which they received from the bombarding neutron. Thus was suggested the breathtaking possibility of obtaining useful power from the disintegration of atoms. Physicists the world over are impatient for the war to end so that they can get back to this research. No gold rush ever held greater enchantment, or greater potential disappointment. The use which we visualize is power to replace coal, and the odds are strongly against us. But the stakes are so high that the research gamble would be justified, even if this were the only possible reward. The prospect of other rewards, at present unsuspected, makes the adventure irresistible. No electrical laboratory with funds and facilities can afford not to have a part in this research.

THE MOST VALUABLE RESULTS OF RESEARCH CANNOT BE PREDICTED

The problems discussed herein are only a small fraction of those awaiting research, and they are merely things that can be seen, that exist already in imagination. They are starting points for research, the objectives which justify it and serve as a basis for its budgets. But, if history repeats itself, the most valuable results will be discoveries made along the road. Often their value is not appreciated at the time. For example, the whole thyratron industry is founded on a chance observation of the behavior of a thoriated tungsten cathode in a gas discharge. It was observed that the filament *did not lose* its monatomic coating of thorium in a gas discharge, when the voltage drop was less than 22 volts, whereas the coating was quickly knocked off at higher voltages. This was the first time that freedom from disintegration had been observed in a low-pressure gas discharge, and it soon led to the development of long-lived gas-discharge devices. But at the time that the observation was made, the rapid disintegration at higher voltages seemed more important than its absence at low voltages.

Such observations become starting points for new research explorations, and so the horizon expands. With each new discovery the thrill of adventure grows, and the desire to pioneer and to risk increases. It is this spirit which our country needs to combat depression and unemployment. It is an infectious spirit, which is caught and propagated in co-operative research groups, and from them can spread through industry and society.

It goes without saying that we are talking about good research, by qualified men with proper backing. It is as easy to throw money away in pseudo-research as on any other bad venture, and there are laboratories in which the prevailing spirit is not that of adventure but of pessimism and defeatism. The spirit of science cannot be mobilized; but it can grow, and there are good research organizations in this country which can serve as nucleuses for such growth. These research centers may be expanded, and new ones may be started with due caution in the choice of leaders and with patience to allow healthy growth.

Such a growth of scientific research, with men of character, imagination, and enthusiasm added as fast as they are available and infected with this spirit of progress and adventure, may leaven our whole economic structure and act as an antitoxin to the dreaded epidemics of depression and unemployment.

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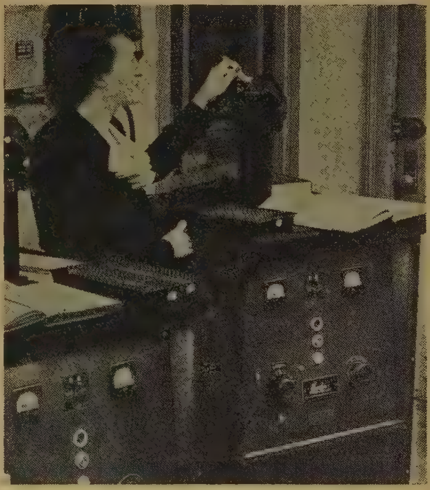


In this X-ray crystal irradiation unit developed by the North American Philips Company in conjunction with the United States Army Signal Corps, the frequency of crystal wafers in the six-to-eight-megacycle-per-second range can be changed from two to three kilocycles per second total. The change is permanent through any probable temperature range

INSTITUTE ACTIVITIES

Program Announced for Winter Technical Meeting, January 22–26, 1945

A program comprised of many wartime developments with interesting postwar applications has been arranged for the AIEE winter technical meeting to be held in New York, N. Y., January 22–26, 1945. Headquarters for the meeting will be in the Engineering Societies' Building. Sessions and conferences closely related to the war effort are as follows: electric welding, industrial control, industrial power applications, influence of aircraft environment on electrical design, aircraft electric apparatus and utilization, aircraft electricity, wartime distribution systems, high-frequency cables, and high-frequency dielectric heating.

JOINT IRE–AIEE SESSION

Continuing the custom of recent years a joint IRE–AIEE session will be held in the Engineering Auditorium on Wednesday evening, January 24. A feature address, "The Navy Electronics Program and Some of Its Past, Present, and Future Problems," by Captain J. B. Dow, United States Navy, will be of interest to a great many members of both organizations.

EDISON MEDAL PRESENTATION

Another feature of the joint session this year will be the presentation of the AIEE Edison Medal to E. F. W. Alexanderson "for his outstanding inventions and developments in the radio, transportation, marine, and power fields." Doctor Alexanderson is consulting engineer with the General Electric Company, Schenectady, N. Y., and a member for life.

SMOKER

The smoker will be held Tuesday evening, January 23, at the Hotel Commodore. This location affords an opportunity for recreation and for getting together with friends amidst pleasant surroundings. Insofar as possible all of the features of this affair will be provided as in previous years. Tickets, including the dinner and show, will be six dollars per person, including tax. Tables for ten can be reserved by advance payment. Checks should be made out to "Special Account, National Secretary, AIEE."

THEATER TICKETS

Every effort is being made to have choice tickets available for the best shows. These are being reserved for the evenings of Wednesday, January 24, and Thursday, January 25. Preference will be given to requests from out-of-town members. Members desiring tickets for specific performances on these or other dates may write to Institute headquarters enclosing checks made out to "Special Account, National Secretary, AIEE. The theater-ticket committee will do its utmost to take care of such requests.

A limited number of seats are now available for "Oklahoma," "Song of Norway," "Voice of the Turtle," and "Bloomer Girl." Ticket prices follow:

Song of Norway	$6.00
Voice of the Turtle	4.20
Oklahoma	4.80
Bloomer Girl	5.40

REGISTRATION AND HOTELS

Members who have received an advance registration card by mail should fill in and return the card promptly. Upon arrival at the meeting members who registered in advance should not fill in another card, but badges should be obtained. A registration fee of two dollars will be charged to all nonmembers except Enrolled Students and the immediate families of members.

Hotel reservations should be made by writing directly to the hotel preferred.

COMMITTEES

The personnel of the 1945 winter technical meeting committee, which is making the arrangements, is as follows: J. F. Fairman, *chairman;* F. A. Cowan, W. S. Hill, M. D. Hooven, A. E. Knowlton, C. S. Purnell, C. C. Whipple, R. J. Wiseman.

W. R. Van Steenburgh is chairman of the smoker committee and C. S. Purnell of the theater and broadcast tickets committee.

JOINT MEETING OF HKN AND TBΠ

Vlademir Karapetoff will give a nonmathematical discussion of "Fundamentals of Relativity" at a joint meeting of Eta Kappa Nu and Tau Beta Pi on Monday evening, January 22. Ladies and guests will be welcome.

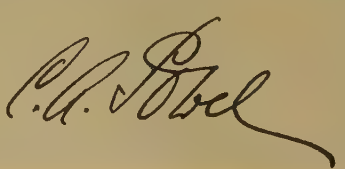
Greetings from the President——

I extend to each of you my personal greetings at the beginning of this new year, which promises to be a momentous one for our nation—for all nations.

The Institute has reason to be proud of its performance during the past year. It has contributed notably to winning the war through its committee work; through the setting up of special standards; through conferences devoted to the solution of many technical problems brought about by the war; and particularly through its many members who have joined the Armed Forces and provided them with a large corps of men with specialized training.

The work is, however, far from finished. With the likelihood of cessation of hostilities in Europe, the Institute and other technical and scientific societies must participate in the all-important work of reorienting our domestic and international economy. We are hopeful that the Government will recognize the past accomplishments of the engineering profession and the assistance that it might render at the peace table and subsequently.

I thank you for your loyal support of the Institute and express my sincere hope that the coming year will bring you the utmost happiness and prosperity.



AIEE Board of Directors Approves Protest on Army–Navy Fee Limit

Endorsement of the resolution adopted by the American Society of Civil Engineers and recommended by the Joint Conference Committee of the Founder Societies protesting the limitation of $25 per day on consulting fees imposed by the Army and Navy Appropriation Acts enacted in July 1943 by Congress recently was announced by AIEE board of directors. The ASCE resolution favors raising the maximum fee to $100 per day on the grounds that the present compensation is wholly inadequate and cannot be expected to command the services of men of the highest qualifications. The text of the resolution follows:

1. *Whereas,* the board of direction of the American Society of Civil Engineers has given consideration to the terms of Congressional Acts which establish $25 per day as compensation for the services of consulting engineers in connection with the design and construction of Federally sponsored projects, and

2. *Whereas,* such compensation is recognized as being wholly inadequate for the character of services required, and

3. *Whereas,* the best interests of the country cannot be served by such requirement for the reason that properly qualified professional engineers of high ability and established reputation cannot be expected to offer their services on such a basis,

4. *Now, therefore be it resolved* that the board of direction of the American Society of Civil Engineers, assembled in session on this tenth day of October 1944, protest the currently established fees and recommend that in future legislation a maximum fee of at least $100 per diem be provided as a basis of compensation for the services of consulting engineers, and

5. *Be it further resolved* that copies of this resolution be furnished to members of Congressional Committees who may be concerned with the framing of appropriate legislation from time to time.

Tentative Winter Technical Meeting Program

Monday, January 22

9:30 a.m. Power Generation

45-4. Evaluation of Electric-Distribution Losses in Terms of Generating-Station-Capacity Investment. **Mario Mortara**, consulting engineer

45-9. Use of Dielectric-Absorption Tests in Drying Out Large Generators. **H. C. Marcroft**, Pennsylvania Water and Power Company

45-34. Frequency Changers—Characteristics, Applications, and Economics. **S. B. Crary, R. M. Easley**, General Electric Company

45-36. Proposed Preferred Standards for Large 3,600-Rpm Three-Phase 60-Cycle Condensing Turbogenerators. Joint Committee on Turbogenerators, AIEE–ASME

9:30 a.m. Temperature Measurements and Standards

45-33. Investigation of Hot-Spot Temperatures In Integral-Horsepower Motors. **L. E. Hildebrand, B. M. Cain, F. D. Phillips**, General Electric Company; **W. R. Hough, J. G. Rosswog**, Reliance Electric and Engineering Company; **C. P. Potter**, Wagner Electric Corporation

45-32. Investigation of Hot-Spot Temperatures in Fractional-Horsepower Motors. **L. H. Hirsch**, Century Electric Company; **R. F. Munier**, Emerson Electric Manufacturing Company; **M. L. Schmidt, L. W. Wightman**, General Electric Company; **J. S. Himebrook**, Master Electric Company; **T. C. Lloyd, O. G. Coffman**, Robbins and Myers, Inc.; **C. P. Potter**, Wagner Electric Corporation

45-37. Temperature Limits and Abstracts of Present Standards and Practices for Stationary-Contact Surfaces. AIEE subcommittee on conduction in stationary contact surfaces

9:30 a.m. Basic Sciences

45-38. Power Geometry of General Transmission Systems. **William Altar**, Westinghouse Electric and Manufacturing Company

45-39. Formulas for Calculating Temperature Distribution in Transformer Cores and Other Electric Apparatus of Rectangular Cross Section. **Thomas J. Higgins**, Illinois Institute of Technology

45-1. Two-Phase Co-ordinates of a Four-Phase Network. **E. W. Kimbark**, Northwestern University

45-40. Transient Response of Controlled-Rectifier Circuits. **P. T. Chin, G. E. Walter**, General Electric Company

2:00 p.m. Conference on Central-Station Auxiliaries

The purpose of this conference is to obtain an informal cross section of existing practice and also to get an expression of ideas in regard to the important subject of station auxiliaries and related problems. The following engineers are expected to participate:

J. B. McClure, General Electric Company

W. R. Brownlee, Commonwealth and Southern Corporation

J. A. Elzi, Commonwealth and Southern Corporation

H. N. Muller, Westinghouse Electric and Manufacturing Company

J. H. Harlow, Philadelphia Electric Company

V. E. McCallum, Commonwealth Edison Company

C. W. Taylor, Sargent and Lundy

R. P. Crippen, Ebasco International Corporation

Many others representing the users, designers, and the manufacturers of equipment have expressed a desire to discuss the subject. Topics anticipated for conference presentations are as follows: power requirements, selection of voltages, type and speed of motors, reliability of power-supply systems, control, and switching and protection of auxiliaries.

2:00 p.m. Electrical Machinery

45-41. Standards and Insulation Characteristics of Oil-Insulated Transformers. **F. J. Vogel**, Illinois Institute of Technology

● PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

● ABSTRACTS of most papers appear on pages 31–9 of this issue and pages 447–8 of the December 1944 issue.

● PRICES and instructions for procuring advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

● COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.

● THE PAPERS regularly approved by the technical program committee ultimately will be published in "Transactions;" many will appear in "Electrical Engineering."

45-42. Measurements of Stray-Load Loss in Induction Motors. **D. H. Ware**, General Electric Company

45-12. Measurement of the Subtransient Impedances of Synchronous Machines. **Gordon F. Tracy**, University of Wisconsin; **W. F. Tice**, Barber-Colman Company

45-2. Damping Effect of D-C Marine Propulsion Motors on Vibrations Produced in Drive Shafts by Large Propellers. **Bernard Litman**, Westinghouse Electric and Manufacturing Company

2:00 p.m. Statistical Methods Applied to Standards

CP.* Fundamental Statistical Tools for Controlling Quality. **J. Manuele, Casper Goffman**, Westinghouse Electric and Manufacturing Company

CP.* Statistical Methods Applied to Insulator Development and Manufacture. **J. J. Taylor**, Ohio Brass Company

CP.* Demerit Schedules of Underwriters' Laboratories. **M. M. Brandon**, Underwriters' Laboratories

CP.* Application of Quality Control to Resistance Welding. **R. S. Inglis, R. P. McCants, L. S. Hobson**, General Electric Company

Tuesday, January 23

9:30 a.m. Circuit Breakers

45-43. Field Tests and Performance on Heavy-Duty High-Speed 138-Kv Circuit Breakers—Oil and Air-Blast. **Philip Sporn, H. P. St. Clair**, American Gas and Electric Service Corporation

45-44. A Three-Cycle 3,500-Megavolt-Ampere Air-Blast Circuit Breaker for 138,000-Volt Service. **H. L. Byrd, B. S. Beall, III**, General Electric Company

45-45. A High-Capacity High-Voltage Three-Cycle Oil Circuit Breaker. **H. L. Byrd, E. B. Rietz**, General Electric Company

45-46. The Next Step in Interrupting Capacity—5,000,000 Kva. **A. W. Hill, W. M. Leeds**, Westinghouse Electric and Manufacturing Company

9:30 a.m. Electric Welding

CP.* Modern Developments in the Use of Arc Welding. **W. J. Conley**, The Lincoln Electric Company

45-29. Analysis of Arc-Welding Reactors. **C. M. Wheeler**, General Electric Company

45-48. The Power-Distribution Problem in Arc Welding. **H. W. Pierce, C. E. Smith**, New York Shipbuilding Corporation

45-28. Power Supply for A-C Arc Welding. **A. U. Welch, R. F. Wyer**, General Electric Company

9:30 a.m. Machinery Insulation

45-49. Insulation-Resistance and Dielectric-Absorption Characteristics of Large A-C Stator Windings. **J. S. Askey, J. S. Johnson**, Westinghouse Electric and Manufacturing Company

45-23. The Application of Silicone Resins to Insulation for Electric Machinery. **J. deKiep, L. R. Hill, G. L. Moses**, Westinghouse Electric and Manufacturing Company

45-30. Organosilicon Compounds for Insulating Electric Machines. **T. A. Kauppi**, Dow Corning Corporation; **G. L. Moses**, Westinghouse Electric and Manufacturing Company

45-50. Rating of High-Temperature Induction Motors. **P. L. Alger, H. A. Jones**, General Electric Company

2:00 p.m. Meeting of Committee on Safety

The committee on safety will hold jointly a committee meeting and a technical conference. Invitation to attend is extended to all members and guests interested in the work of this committee.

2:00 p.m. Mercury-Arc Rectifiers and Protection

45-20. Arc-Backs in Rectifier Circuits—Artificial Arc-Back Tests. **R. D. Evans, A. J. Maslin**, Westinghouse Electric and Manufacturing Company

45-51. Rectifier Fault Currents. **C. C. Herskind, H. L. Kellogg**, General Electric Company

45-52. Anode-Circuit-Breaker Design and Performance Criteria. **E. W. Boehne, W. A. Atwood**, General Electric Company

45-53. Voltage and Current Relations for Controlled Rectification With Inductive and Generative Loads. **K. P. Puchlowski**, Westinghouse Electric and Manufacturing Company

2:00 p.m. Protective Devices

45-54. Improved Fault Protection for Rural Distribution Systems. **A. Van Ryan**, Kyle Corporation

45-8. Graphical Method of Calculating Fault Currents on Rural Distribution Systems. **F. W. Linder**, Rural Electrification Administration

45-55. Rectifier Relay for Transformer Protection. **E. L. Michelson**, Commonwealth Edison Company

45-56. New Solenoid Mechanism for Magne-Blast Breaker.B. **W. Wyman, J. H. Keagy**, General Electric Company

45-57. Nine Years' Experience With Ultrahigh-Speed Reclosing of High-Voltage Transmission Lines. **Philip Sporn, C. A. Muller**, American Gas and Electric Service Corporation

2:00 p.m. Electric Machinery

45-16. Inherent Errors in the Determination of Synchronous-Machine Reactances by Test. **C. Concordia, F. J. Maginniss**, General Electric Company

45-22. Damping and Synchronizing Torques of Power Selsyns. **C. Concordia, Gabriel Kron**, General Electric Company

45-14. Transient Electrical Torques of Turbine Generators During Short Circuits and Synchronizing. **H. S. Kirschbaum**, Westinghouse Electric and Manufacturing Company

45-15. Determination of Transient Shaft Torques in Turbine Generators by Means of the Electrical—Mechanical Analogy. **G. D. McCann, C. E. Warren, H. E. Criner**, Westinghouse Electric and Manufacturing Company

6:30 p.m. Smoker at Hotel Commodore

*CP: Conference paper; no advance copies are available; not intended for publication in *Transactions*.

Wednesday, January 24

10:00 a.m. General Session

Feature talk on a timely topic that will be of interest to many members. To be announced later.

2:00 p.m. Cables and Corrosion

45-58. THE DIELECTRIC STRENGTH AND LIFE OF IMPREGNATED PAPER—IV. **J. B. Whitehead, J. M. Kopper,** The Johns Hopkins University

45-59. ELECTROLYSIS AND CORROSION OF UNDERGROUND POWER-SYSTEM CABLES. **L. J. Gorman,** Consolidated Edison Company of New York, Inc.

45-60. GALVANIC CORROSION OF SOIL WATERS. **H. S. Phelps, F. Kahn,** Philadelphia Electric Company

45-61. STUDY OF A-C SHEATH CURRENTS AND THEIR EFFECT ON LEAD-CABLE SHEATH CORROSION. **C. M. Sherer,** Pennsylvania Water and Power Company; **K. J. Granbois,** Safe Harbor Water Power Corporation

2:00 p.m. Industrial Control

45-27. VARIABLE-UNBALANCED-VOLTAGE CONTROL. **W. R. Wickerham,** Westinghouse Electric and Manufacturing Company

45-62—ACO.** PRINCIPLES OF GRID CONTROL FOR THYRATRONS. **P. H. Chin, E. E. Moyer,** General Electric Company

45-64. AN INTERVAL TIMER FOR ARC DURATION. **J. S. Quill,** General Electric Company

2:00 p.m. Instruments and Measurements

45-24. ORTHOMAGNETIC BUSHING CURRENT TRANSFORMER FOR METERING. **A. Boyajian, G. Camilli,** General Electric Company

45-19. A MODULATED-FREQUENCY SYSTEM OF TELEMETERING. **H. E. Renfro, A. P. Peterson,** Control Corporation

45-65. DYNAMIC MEASUREMENTS ON ELECTROMAGNETIC DEVICES. **E. L. Norton,** Bell Telephone Laboratories, Inc.

45-66. A PORTABLE INSTRUMENT FOR MEASURING INSULATION RESISTANCE AT HIGH VOLTAGE. **F. W. Atkinson, R. B. Taylor,** The Takk Corporation

2:00 p.m. Conference on Relay Protection of Generators

8:00 p.m. Joint IRE–AIEE Session

Edison Medal presentation
Address: THE NAVY ELECTRONICS PROGRAM AND SOME OF ITS PAST, PRESENT, AND FUTURE PROBLEMS. Captain J. B. Dow, United States Navy

Thursday, January 25

9:30 a.m. Lightning

45-67. IMPEDANCES SEEN BY RELAYS DURING POWER SWINGS WITH AND WITHOUT FAULTS. **Edith Clarke,** General Electric Company

45-18. LIGHTNING INVESTIGATION OF 132-KV SYSTEM OF AMERICAN GAS AND ELECTRIC COMPANY. **I. W. Gross, G. D. Lippert,** American Gas and Electric Service Corporation

45-26. LIGHTNING INVESTIGATION ON TRANSMISSION LINES—VIII. **W. W. Lewis, C. M. Foust,** General Electric Company

9:30 a.m. Communication

45-68. A COMPARISON OF THE AMPLITUDE-MODULATION, FREQUENCY-MODULATION, AND SINGLE-SIDE-BAND SYSTEMS FOR POWER-LINE CARRIER TRANSMISSION. **R. C. Cheek,** Westinghouse Electric and Manufacturing Company

45-69. THE RESISTANCE-COUPLED AMPLIFIER. **L. G. Cowles,** The Texas Company

45-70. THE TAPERED TRANSMISSION LINE. **J. W. Milnor,** Consulting Engineer

**ACO: Advance copies only available; not intended for publication in *Transactions*.

9:30 a.m. Industrial Power Applications

45-47. TRACER-CONTROLLED POSITION REGULATOR FOR PROPELLER MILLING MACHINE. **C. R. Hanna, W. O. Osbon,** Westinghouse Electric and Manufacturing Company; **R. A. Hartley,** Adel Precision Products Corporation

45-71. APPLICATION OF ELECTRIC EQUIPMENT FOR PROPELLER MILLING MACHINE. **H. E. Morton,** Morton Manufacturing Company; **O. G. Rutemiller,** Crosley Corporation

45-35. DESIGN OF SEALED IGNITRON RECTIFIERS FOR THREE-WIRE SERVICE. **M. M. Morack,** General Electric Company

45-72. APPLICATION OF CAPACITORS FOR POWER-FACTOR IMPROVEMENT OF INDUCTION MOTORS. **W. C. Bloomquist, W. K. Boice,** General Electric Company

9:30 a.m. Aircraft Electric Apparatus and Utilization

45-3. SPEED-CONTROL SYSTEM FOR AN AIRCRAFT CABIN-SUPERCHARGER DRIVE. **F. W. Godsey, J. D. Miner, Jr., O. C. Walley,** Westinghouse Electric and Manufacturing Company

45-81. THE AMPLIDYNE GENERATOR APPLIED TO SPEED-CONTROLLED ELECTRIC GUN TURRETS FOR AIRCRAFT. **L. A. Zahorsky,** General Electric Company

45-82. 400-CYCLE INVERTERS FOR MILITARY AIRCRAFT. **C. P. Hayes, L. L. Ray,** General Electric Company

45-6. AIRCRAFT ILLUMINATION. **W. W. Davies,** United Air Lines, Inc.

2:00 p.m. Supervisory Control and Stability Improvement

45-77. THE COMBINATION OF SUPERVISORY CONTROL WITH OTHER FUNCTIONS ON POWER-LINE CARRIER CHANNELS. **R. C. Cheek, W. A. Derr,** Westinghouse Electric and Manufacturing Company

45-7. SUPERVISORY CONTROL FOR NEW CHICAGO SUBWAY. **W. A. Derr,** Westinghouse Electric and Manufacturing Company; **C. J. Buck,** Chicago Rapid Transit Company; **J. A. Stoos,** Department of Subways and Superhighways, City of Chicago

45-78. POWER-LINE CARRIER CHANNELS. **M. J. Brown,** Westinghouse Electric and Manufacturing Company

45-13. IMPROVING STABILITY BY RAPID CLOSING OF BUS-TIE SWITCHES. **E. W. Kimbark,** Northwestern University

2:00 p.m. Land Transportation

45-31. COMPRESSED-AIR CIRCUIT BREAKERS IN A-C RAILWAY SERVICE. **H. M. Wilcox, D. C. Harker,** Westinghouse Electric and Manufacturing Company

45-17. MERCURY-ARC RECTIFIERS FOR RAILROADS. **S. S. Watkins,** Gibbs and Hill, Inc.

45-10. ELECTRIFICATION AND SIGNALING OF THE CANADIAN NATIONAL RAILWAYS' TERMINAL AT MONTREAL, CANADA. **R. G. Gage,** Canadian National Railways

45-11. GROUNDING OF CIRCUITS ON SELF-PROPELLED VEHICLES. **D. D. Ewing,** Purdue University

2:00 p.m. Industrial Power Applications

45-25. THE DESIGN OF BUS-BAR INDUSTRIAL DISTRIBUTION SYSTEMS: AN EPITOMIZATION OF AVAILABLE DATA. **T. J. Higgins,** Illinois Institute of Technology

45-21. DODGE CHICAGO PLANT'S ELECTRIC-POWER-DISTRIBUTION SCHEME WITH AIRPLANE-ENGINE-TESTING POWER RECOVERY. **E. L. Bailey,** Chrysler Corporation

45-79. MODERN ELECTRIC-POWER-DISTRIBUTION IDEAS AS APPLIED IN A LARGE WAR PLANT. **R. H. Kaufmann,** General Electric Company; **N. A. Kieb,** Pratt and Whitney Aircraft Corporation

45-80. INDUCTION HEATING OF MOVING STRIP. **R. M. Baker,** Westinghouse Electric and Manufacturing Company

2:00 p.m. The Influence of Aircraft Environment on Electrical Design

45-73. ELECTROLYTIC CORROSION—METHODS OF EVALUATING INSULATING MATERIALS USED IN TROPICAL SERVICE. **B. H. Thompson, K. N. Mathes,** General Electric Company

45-5. SIMULATED-HIGH-ALTITUDE TESTING OF AIRCRAFT IGNITION CABLES AND CONNECTORS. **H. H. Race, A. M. Ross, Jr.,** General Electric Company

45-74. PREFERRED PRACTICES FOR ELECTRIC CONTROL DEVICES FOR AIRCRAFT. **F. W. Hottenroth, Jr.,** General Electric Company

45-75. EFFECT OF ALTITUDE ON TEMPERATURE RISE OF AIRCRAFT TRANSFORMERS. **V. M. Montsinger,** General Electric Company. Presentation by title

45-76. VIBRATION INSULATION AND STRUCTURAL RUBBER. **J. A. Connon,** United States Rubber Company. Presentation by title

Friday, January 26

9:30 a.m. Conference on Wartime Practices on Distribution Systems and Their Effect on System Operation and Future Designs

This conference is being sponsored by the committee on power transmission and distribution to ascertain the effect of wartime restrictions on power-distribution-system operating and design practices. The committee anticipates a free discussion, representative of present-day thinking, which might assist in establishing more clearly the probable effects of this thinking upon future distribution-system, substation, and circuit designs and upon operating experience. Subjects tentatively selected for discussion, upon which data are being prepared for presentation, are:

CP.* ANALYSIS OF AVAILABILITY OF EQUIPMENT AS EFFECTED BY PREARRANGED MAINTENANCE REQUIREMENTS AND CAPACITY LIMITATIONS RESULTING FROM EQUIPMENT

CP.* ANALYSIS OF CUSTOMER-SERVICE INTERRUPTIONS AS A MEANS OF DETERMINING ACCEPTABILITY OF DESIGNS FOR METHODS OF SUPPLY

CP.* LIMITING EFFECT OF AUXILIARY EQUIPMENT, SUCH AS CONNECTORS AND CLAMPS, UPON THE RATINGS OF OVERHEAD CONDUCTORS

CP.* TENDENCIES TOWARD CHANGES IN DESIGN AND OPERATING PRACTICES AS A RESULT OF RECENT EXPERIENCES

This conference will be informal, and any related subjects can be developed during the discussion.

9:30 a.m. Conference on High-Frequency Cables

This conference is sponsored by the committee on communication with the co-operation of the Army–Navy *RF* cable co-ordinating committee. The subject will be the design and manufacture of radio-frequency solid-dielectric cables. Topics to be discussed will include requirements and design criteria for cable structures, properties and manufacture of polyethylene, extrusion and manufacture of flexible cables, and methods of testing cables through the whole spectrum up to several thousand megacycles. The conference will be conducted under the general guidance of Lieutenant Commander John H. Neher, United States Naval Reserve, with several qualified topic leaders. It is expected that many members will wish to contribute to the discussion, and it is hoped also that a co-ordinated conference report may be made available later.

9:30 a.m. Conference on High-Frequency Dielectric Heating

2:00 p.m. Conference on Industrial System and Apparatus Voltage Ratings

This conference will discuss system and apparatus voltage ratings from the standpoint of industrial user. Participating:

Howard P. Seelye, Detroit Edison Company
T. C. Duncan, Consolidated Edison Company of New York, Inc.
Don Beeman, General Electric Company
F. W. Cramer, Carnegie-Illinois Steel Company
K. K. Falk, Bendix Aviation Corporation
R. T. Woodruff, Aluminum Ore Company
John M. Webb, Eli Lilly Company

The committee on industrial power applications believes this symposium will do much to clarify the problem as it affects industrial users of electric apparatus and at the same time present an opportunity for the presentation of the viewpoints of the utilities and the manufacturers.

2:00 p.m. Conference on Air Transportation

2:00 p.m. Conference on Domestic and Commercial Applications

Expense Awards Established From Members-for-Life Fund

Utilization of the member-for-life fund to defray the expenses of District Branch paper prize winners to the summer meeting where they would present their papers has been announced by the standing committee in charge of the administration of the fund. These annual member-for-life awards are to be established as follows:

1. The payment of the expenses of five District Branch paper prize winners to the summer technical meetings of the Institute to present their papers on the regular technical program of the meeting.

2. The awards to be available to the even-numbered Districts for the summer technical meeting held in the even-numbered years and to the odd-numbered Districts in the odd-numbered years.

3. The expenses to be paid in the form of an allowance of nine cents per mile one way from the award winner's home town to the place of the summer technical meeting plus a reasonable allowance per day for the official duration of the meeting.

The member-for-life fund was set up at the January 1944 meeting of the AIEE board of directors by the approval of recommendations that the voluntary dues payments made by members-for-life be kept in a separate fund in the custody of the treasurer of the Institute. This fund is to be used only for such special purposes as will aid the objectives of the Institute, these purposes to be determined by a designated administrative committee.

The committee's decision to use this income for the establishment of annual member-for-life awards is applicable to the 1945 and 1946 summer meetings only. It will be determined from the experience gained whether or not to continue utilizing the fund for this purpose.

AIEE Nominating Committee for 1944–45 Announced

The national nominating committee of the AIEE, in accordance with the Institute's bylaws, will meet during the winter technical meeting January 22–26, 1945, in New York, N. Y., to nominate candidates for national offices to be voted on by the membership in the spring of 1945. Members of the national nominating committee are as follows:

Representing the board of directors

L. Alger, General Electric Company, Schenectady, N. Y.

T. Henry, Buffalo Niagara Electric Corporation, Buffalo, N. Y.

G. LeClair, Commonwealth Edison Company, Chicago, Ill.

H. Mortensen, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

W. Ricker, Tulane University, New Orleans, La.

Alternates:

F. Fairman, Consolidated Edison Company of New York, Inc., New York, N. Y.

E. Funk, Philadelphia Electric Company, Philadelphia, Pa.

Representing the ten geographical Districts

F. S. Bacon, Jr., Westinghouse Electric and Manufacturing Company, Boston, Mass.

F. J. Chesterman, Bell Telephone Company of Pennsylvania, Philadelphia, Pa.

M. D. Hooven, Public Service Electric and Gas Company, Newark, N. J.

4. J. D. Harper, Aluminum Company of America, Alcoa, Tenn.

5. J. E. Hobson, Illinois Institute of Technology, Chicago, Ill.

6. I. M. Ellestad, Northwestern Bell Telephone Company, Omaha, Nebr.

7. M. C. Hughes, Agricultural and Mechanical College of Texas, College Station, Tex.

8. F. C. Lindvall, California Institute of Technology, Pasadena, Calif.

9. Joseph Hellenthal, Puget Sound Power and Light Company, Seattle, Wash.

10. D. G. Geiger, Bell Telephone Company of Canada, Toronto, Ont.

Alternate:

6. M. L. Burgess, Westinghouse Electric and Manufacturing Company, Omaha, Nebr.

Future AIEE Meetings

Winter Technical Meeting
New York, N. Y., January 22–26, 1945

North Eastern District Meeting
Buffalo, N. Y., April 25–26, 1945

Summer Technical Meeting
Detroit, Mich., June 25–29, 1945

Committee Will Award Fortescue Fellowship for 1945–46

The normal procedure for awarding the Fortescue fellowship which has been hampered by the war's removing most of the eligible candidates from scholastic pursuits since 1942 will be resumed for the college year 1945–46. Application blanks are being mailed to accredited schools and also may be obtained from the AIEE National Secretary.

Established in 1940, the award was made only once when it went to Norman Z. Alcock, Kingston, Ontario, Canada, for the year 1940–41, before it was suspended because of the war. The fellowship of $500 or more was made possible through a trust fund set up by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., under the sponsorship of the AIEE as a memorial to Charles LeGeyt Fortescue (A '03, F '21) in recognition of his contributions to the electric-power industry.

ABSTRACTS . . .

TECHNICAL PAPERS previewed in this section will be presented at the AIEE winter technical meeting, New York, N. Y., January 22–26, 1945, and will be distributed in advance-pamphlet form as soon as they become available. Copies may be obtained by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstract, or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk.

Mail orders will be filled
AS PAMPHLETS BECOME AVAILABLE

Air Transportation

45-73—Electrolytic Corrosion—Methods of Evaluating Insulating Materials Used in Tropical Service; *B. H. Thompson, K. N. Mathes (M '43). 20 cents.* The selection of insulating materials to guard against electrolytic corrosion has become increasingly important, as the use of electric devices in the tropics has increased. Moisture conditions in the tropics are described, and means for producing such conditions in the laboratory are considered. The visual, corrosion-current, and water-extract-conductivity methods for studying electrolytic corrosion are described. Typical results for a number of different materials are given.

45-74—Preferred Practices for Electric Control Devices for Aircraft; *F. W. Hottenroth, Jr. 15 cents.* This paper points out the need for design standards for electric equipment used on aircraft. It suggests that the AIEE set up standards of preferred practices for electric control equipment for planes and includes a sample set of standards as a starting point for discussion. These standards include such items as: temperature rise of coils, vibration tests, and creepages. The paper also describes certain design features which have been found particularly advantageous under the special conditions encountered on planes. It indicates that double-break contacts are especially suited for high-altitude operation on 24-volt systems and shows a close co-ordination between single-break contact ratings at 12 volts direct current and double-break ratings at 24 volts direct current.

45-81—The Amplidyne Generator Applied to Speed-Controlled Electric Gun Turrets for Aircraft; *L. A. Zahorsky (A '42). 20 cents.* A particular type of Amplidyne generator which develops readily controlled power for aircraft machine-gun turrets has attained widespread usage in the field of aircraft utilizing electric gun turrets. The functions of the turret power drive, a brief description of the Amplidyne, and the details of the Amplidyne characteristics measured in terms of the turret operation are of value in understanding the purpose of the Amplidyne generator. Some of the advantages of separating the Amplidyne characteristics from those of the entire turret performance in design, trouble shooting, and in application are discussed. A working specification for the Amplidyne, in terms of the turret control system, and another set of specifications for the Amplidyne alone are presented in conclusion.

45-82—400-Cycle Inverters for Military Aircraft; *C. P. Hayes (A '41), L. L. Ray (A '44). 15 cents.* Modern military aircraft require an a-c power supply for radio, radar, gyro compasses, and other control equipment. The a-c power usually is obtained from conversion equipment which converts the d-c supply of the engine generators and batteries to alternating current. This paper discusses the type of inverters and describes a 1,500 volt-ampere inverter which the authors designed. This discussion includes details of frequency and voltage regulators, as well as improvements in ventilation and brush life. Illustrations of several types of inverters, speed regulators, and voltage regulators are included.

45-75—Effect of Altitude on Temperature Rise of Aircraft Transformers; *V. M. Montsinger (F '29). 15 cents.* As aircraft transformers are required to operate at ex-

tremely high altitudes, it is important to know how changes in the air density affect their temperature rise. It is pointed out that the effect of altitude on transformers can vary as much as 2.5:1, depending on the nature of the cooling surfaces which govern the percentages of loss by radiation and by connection. If these percentages are known (at sea level), it should be possible to predetermine the effect of altitude on any design of transformer, or on any kind of electric apparatus. A method for estimating the effect of altitude is given, and calculations obtained by the method are found to check quite closely the results of tests made on a two-kilovolt-ampere aircraft transformer under conditions representing a range in altitude from sea level to 40,000 feet.

45-76—Vibration Insulation and Structural Rubber; *J. A. Connan. 20 cents.* The purpose of this paper is to present to the engineer concerned with the protection of delicate equipment, a compilation of information on the fundamentals of mechanical vibrations and the properties of structural rubber. Vibration-insulation problems can be classified in two categories:

1. Problems involving the insulation from its surroundings of a unit originating vibration—an airplane engine, or instance.
2. Problems involving the protection of a delicate unit from external vibration—a radio set in an airplane is an example.

The paper then goes on to explain the fundamentals of mechanical vibration insulation by means of rubber mounting. This is divided broadly into two parts:

1. Fundamentals of the application of rubber mountings.
2. Structural characteristics of rubber as used in rubber mountings.

A number of practical formulas are included.

Basic Sciences

45-38—Power Geometry of General Transmission Systems; *William Altar (A '42). 20 cents.* A new geometrical relation between coexisting points in the complex charts of sender and receiver power is presented, with particular attention to circular contour lines and circle diagrams. To establish the relation, sender and receiver charts must be plotted in two separate co-ordinate systems of specified position. A pictorial interpretation in terms of a projective relation, not unlike a stereographic projection, also is offered. The results suggest a simple graphical procedure for the solution of transmission problems, not only as encountered in the field of power transmission but, also broadly speaking, wherever one deals with four-terminal networks. In the field of a-c machinery, for instance, a rigorous circle diagram for the induction-motor results as a direct consequence of the new approach.

45-39—Formulas for Calculating Temperature Distribution in Transformer Cores and Other Electric Apparatus of Rectangular Cross Section; *T. J. Higgins (A '40). 20 cents.* Formulas are derived for calculating the temperature distribution, maximum temperature, and average temperature in electric devices of rectangular cross section whereof geometric and surface conditions are such that the temperature distribution is substantially independent of the co-ordinate perpendicular to the plane of the cross section. This category comprises transformer cores, certain shapes of electric coils, bus bars, and other electrical apparatus. A rigorous solution is obtained for the following two-dimensional boundary-value problem in the mathematical theory of heat. To determine the expressions for the temperature distribution, maximum temperature, and average temperature in an infinite cylinder of rectangular cross section:

1. Wherein the heat developed per unit time per unit volume is a given linear function of the temperature.
2. Whereof the surface condition is that common to practice—at a point in the surface the difference between the temperatures of the surface and the immediately adjacent ambient medium is proportional to the outward normal derivative of the temperature.
3. This proportionality constant is taken differently on each of the four edges of the cross section.
4. The temperature distribution in the immediately adjacent ambient is assumed arbitrary, providing only that it be expressible in a generalized Fourier series over each edge of the cross section.

The desired expressions for this heat problem are obtained in the usual fashion: by combining particular solutions of the definitive differential equation, which are expressed as generalized double Fourier series with constant coefficients so determined that the boundary conditions are satisfied. Certain convenient special forms of the general expressions for T, T_m, and T_a are derived. Application of these formulas in calculating temperature distribution in electric apparatus stems from identification of the physical constants of a particular electric device with the corresponding constants of the general heat problem. Illustratively, the maximum temperature in a single-phase transformer is calculated and found to be almost identical with the measured experimental value. Calculation of the temperature distribution in toroidal electric coils is discussed concisely. Mention is made of other apparatus to which the formulas are applicable.

45-40—Transient Response of Controlled-Rectifier Circuits; *P. T. Chin (A '41), G. E. Walter (A '44). 25 cents.* Transients in circuits supplied by controlled rectifiers using gas- or mercury-vapor-filled electron tubes are found analytically by an extended superposition method. Loads containing resistance, inductance, and a counter electromotive force are studied, and results are obtained for both rectification and inversion. Examples are based on the half-wave biphase rectifier, and the appendix contains an analysis of a *p*-phase rectifier. The assumptions include constant circuit parameters, a fixed firing angle during transients, continuous-load current, and no leakage reactance in the supply transformer.

Communication

45-68—A Comparison of the Amplitude-Modulation, Frequency-Modulation, and Single-Side-Band Systems for Power-Line Carrier Transmission; *R. C. Cheek (A '42). 20 cents.* Many utility engineers interested in increasing the applications of power-line carrier on their systems are confronted with the difficult problem of finding space in an already crowded carrier-frequency spectrum for additional carrier channels. Other problems are introduced by the long distances and attendantly high attenuation and noise levels through which some carrier equipment must work. In general, a mere increase in the power of ordinary amplitude-modulated equipment is not a satisfactory solution to these problems. These facts have led to a consideration of the characteristics at power-line carrier frequencies of two fundamentally different systems of transmission, the frequency-modulation and the single-side-band systems. In this paper these systems are compared with the more familiar amplitude-modulation system on the basis of channel-width requirements, ability to work through high attenuation and noise levels, and other characteristics. The paper also discusses applications of the single-side-band system that are not possible with other systems in which a continuous carrier is transmitted.

45-69—The Resistance-Coupled Amplifier; *L. G. Cowles (A '31). 25 cents.* This paper presents practical methods for the coupling-circuit design of audio-frequency resistance-coupled amplifiers, and methods for determining the characteristics of a vacuum tube having a resistor in its external plate circuit. The material includes:

1. The classical solution of the coupling network rearranged for rapid calculations, with charts for determining the band width and coupling loss of the tuned amplifier.
2. A new method employing an equivalent circuit for determining the phase and amplitude characteristics of the resistance-coupled amplifier, including the narrow-band case without approximations.
3. A set of rules and charts for determining the electrode voltages and dynamic constants of a class-*A* vacuum tube having a resistor in its external plate circuit.
4. A simple circuit with which the dynamic constants and gain of a tube in resistance coupling can be measured, and with which it is easy to observe the gain and wave form obtainable with various tubes under different conditions of operation.

The methods presented in this paper can be applied easily and have been found to be of practical value in the design and application of the resistance-coupled amplifier.

45-70—The Tapered Transmission Line; *J. W. Milnor (F '30). 15 cents.* The computation of the performance of a telegraph or telephone transmission line in which the parameters vary along the line generally is quite involved. However, by restricting the variations to certain preferred plans of tapering, the computations become much simplified and do not exceed greatly in complexity those for the line with parameters constant along its length. Working formulas are included in the paper. The preferred plans are in fact those which would be chosen, when it is desired to provide most efficient transfer of energy.

Electric Machinery

45-12—Measurement of the Subtransient Impedances of Synchronous Machines; *G. F. Tracy (A '26), W. F. Tice. 15 cents.* A method of measuring the direct-axis and the quadrature-axis subtransient impedances of a synchronous motor or generator is described, in which three-phase voltages are

impressed on the machine at standstill, and appropriate instrument readings are taken from which the positive-sequence and the negative-sequence components of the voltages and currents are obtained. These values of symmetrical components then are substituted in a pair of formulas, which yield the desired impedances. The principal advantage of this new method is that it is not necessary to set the field structure of the machine in any specific position as in the present single-phase test, a requirement that may be troublesome in the case of large machines. Since the formulas contain a term involving the angle by which the pole axis is displaced from a reference phase, a simple test is described whereby this angle may be obtained.

45-16—Inherent Errors in the Determination of Synchronous-Machine Reactances by Test; *C. Concordia* (*M '37*), *F. J. Maginniss* (*A '43*). *25 cents.* This paper presents the results of a study of proposed methods of measuring synchronous-machine transient and subtransient reactance. The utilization of the symmetrical and asymmetrical components of short-circuit current, as given by the AIEE Test Code, is discussed, and the effects of machine saliency and sequential closing are determined. As a result of this study, various modifications of the short-circuit test methods are proposed.

45-14—Transient Electrical Torques of Turbine Generators During Short Circuits and Synchronizing; *H. S. Kirschbaum* (*A '43*). *15 cents.* During faults on turbine generators, and during synchronizing, the torques acting on the rotor of the machine may reach values of 15 or 20 times the rated torque of the machine. This is especially true of modern two-pole turbine generators. The problem of determining coupling and shaft stresses during such periods must proceed from a knowledge of the electric torque acting on the rotor. This paper presents a method of calculating the alternating and unidirectional torques which act on the rotor and a physical explanation of the origin of these components of torque.

45-15—Determination of Transient Shaft Torques in Turbine Generators by Means of the Electrical–Mechanical Analogy; *G. D. McCann* (*M '44*), *C. E. Warren* (*A '41*), *H. E. Criner*. *15 cents.* A description is given of a new method and device (the mechanical transients analyzer) for solving a wide range of transient-vibration problems by the principle of electrical–mechanical analogy. This device has been applied to a study of the transient torques developed in the shafts of turbine generators during such disturbances as synchronization out of phase and electric-system faults. A general analysis is presented of the characteristics of the shaft torque under various system-fault conditions showing the relative effects of the resulting electric-rotor air-gap torques for a range of mechanical system constants. Illustrations also are given of the use of the analyzer for several other vibration problems.

45-22—Damping and Synchronizing Torques of Power Selsyns; *C. Concordia* (*M'37*), *Gabriel Kron* (*A'30*). *25 cents.* When Selsyns are used as one of the power-amplifying stages of a control system, it is necessary to determine the hunting characteristics of these machines as affected by speed, load, oscillation frequency, and various design factors. As the direct calculation of these characteristics is difficult, this paper develops equivalent circuits that enable one to use the a-c network analyzer directly to measure the damping and synchronizing torques of Selsyns as affected by these various factors. Results of such studies made of specific balanced Selsyn systems are presented. Also, a principle of considerable generality is given stating the condition for stability of a power-Selsyn drive.

45-23—The Application of Silicone Resins to Insulation for Electric Machinery; *J. DeKiep* (*M '43*), *L. R. Hill*, *G. L. Moses* (*A '43*). *20 cents.* Experience with the application of silicone resins is described, including laboratory tests on materials and coils, as well as laboratory tests on rotating apparatus. Practical problems regarding the use of these materials are discussed and recommendations made for obtaining an adequate high-temperature insulation. Thermal aging tests are reported and recommendations made as to tentative temperature limits for general rating and application purposes.

45-27—Variable-Unbalanced-Voltage Control for Wound-Rotor Motors; *W. R. Wickerham*. *15 cents.* The application of variable unbalanced voltage to the primary winding of a polyphase induction motor represents a new departure in the design of control for this type of motor. The degree of unbalance varies automatically in response to speed, and the responsiveness is adjustable so that, compared to any single system now in use, a wider range of speed control through the complete load range is attainable. The speed–torque characteristics bear a considerable resemblance to those developed by a d-c motor operating with armature shunt. Abnormal input current, ordinarily associated with the application of unbalanced voltage to a motor, has been eliminated. Input current and motor-winding heating is only slightly in excess of that attendant on standard operation, and this is particularly true for the heavier loads and slower speeds.

45-30—Organosilicon Compounds for Insulating Electric Machines; *T. A. Kauppi* (*A '44*), *G. L. Moses* (*M '44*). *20 cents.* The general problem of electrical insulation is reviewed in relation to silicone insulating materials. Silicone compounds are described and their chemical and physical characteristics discussed. Thermal stability and moisture resistance of silicone insulation are compared with that of conventional class-*A* and class-*B* insulation. Predictions are made as to the field of usefulness of silicones in electrical insulation. Recommendations are made for widespread investigation to evaluate the over-all advantages of this new type of insulation.

45-41—Standards and Insulation Characteristics of Oil-Insulated Transformers; *F. J. Vogel* (*M '41*). *15 cents.* The strength of the insulation in transformers to resist various types of voltage stress is very important. The service and life of the transformer is partially dependent on the insulation strength, and in recognition of this fact standards for insulation strength have long been established. In the course of time, improvements have taken place in design, new applications have been created, and we have learned more about the nature of stresses which arise in service. Service conditions, too, probably will change in the future, which will require changes in insulation requirements. Therefore it is natural that gradual changes in the standards and additions to them have taken place, with the result that sometimes they are not entirely consistent. It is desired in this paper to point out some inconsistencies and propose certain changes in the standards which might be given consideration. Experience has shown that ability to withstand the applied 60-cycle test or 120-cycle induced test is no proof of a transformer's ability to withstand impulse tests. Therefore, it would be desirable to apply impulse tests to all transformers as a specified commercial test. It would be desirable to change the present tests, if any economies would result and if the testing procedure would be simplified. It is suggested that a three-microsecond, or a one-microsecond, or a steep-front impulse test might be substituted for the present applied or induced tests. Since the full-wave test is necessary, it should be retained. Probably it would be desirable also to retain a two times induced test as a last test for all transformer windings. If the one-microsecond test at the correct level were used, it would ensure the three-microsecond value without making another test.

45-32—Investigation of Hot-Spot Temperature in Fractional-Horsepower Motors; *L. H. Hirsch*, *R. F. Munier* (*A '32*), *M. L. Schmidt* (*M '43*), *L. W. Wightman*, *J. S. Himebrook* (*M '39*), *T. C. Lloyd* (*A '31*), *O. G. Coffman*, *C. P. Potter* (*F '29*). *25 cents.* This paper is a summary of the data presented at a technical conference at the AIEE 1944 summer technical meeting, by the authors. It contains data comparing the temperature rise by thermometer, surface thermocouple, resistance, and embedded detector on open and totally enclosed, nonventilated, fractional-horsepower motors. It is hoped that this information will be useful to the AIEE on electrical machinery, the *C*-50 Committee of the American Standards Association, and the general engineering committee of the motor and generator section of the National Electrical Manufacturers Association, and that it will be used to make revisions which will bring the various temperature standards for fractional-horsepower motors into line.

45-33—Investigation of Hot-Spot Temperatures in Integral-Horsepower Motors; *L. E. Hildebrand* (*M '21*), *B. M. Cain* (*A '34*), *F. D. Phillips* (*M '35*), *W. R. Hough* (*M '41*), *J. G. Rosswog* (*A '41*), *C. P. Potter* (*F '29*). *15 cents.* This paper is a summary of the data presented at a technical conference at the AIEE 1944 summer technical meeting, by the authors. It contains data comparing the temperature rise by thermometer, surface thermocouple, resistance, and embedded detectors in open, totally enclosed, nonventilated, and totally enclosed fan-cooled motors. It is hoped that this information will be useful to the AIEE committee on electrical machinery, the *C*-50 committee of

American Standards Association, and the general engineering committee of the motor and generator section of the National Electrical Manufacturers Association, and that it will be used to make revisions which will bring the various temperature standards for integral-horsepower motors into line.

45-42—Measurement of Stray-Load Loss in Induction Motors; *D. H. Ware.* *15 cents.* In 1939, T. H. Morgan, W. E. Brown, and A. J. Schumer presented a paper proposing the reverse-rotation test for direct measurement of stray-load loss in induction machines. This test has proved to be accurate for small motors but is not accurate for large motors or high-speed motors of intermediate size and larger. This paper proposes a modification of Professor Morgan's method, and presents test data to show that this modification brings the reverse-rotation test into agreement with the input-output efficiency test for all sizes of motors.

45-49—Insulation-Resistance and Dielectric-Absorption Characteristics of Large A-C Stator Windings; *J. S. Askey (A'39), J. S. Jornson (A'36).* *20 cents.* Insulation-resistance and dielectric-absorption characteristics are presented; which give a comprehensive picture of average and normal variations in the insulation characteristics of new large a-c stator windings. Temperature-insulation resistance characteristics are discussed. Considerations involved in the selection of formulas for safe minimum values of insulation resistance are discussed. Insulation characteristics are examined on a sufficiently large number of machines to give good statistical data.

45-50—Rating of High-Temperature Induction Motors; *P. L. Alger (F'30), H. A. Jones.* *15 cents.* The advent of new high-temperature insulating materials, such as the silicones, gives new freedoms to the motor designer. It is probable, however, that factors other than insulation will limit the desirable motor temperature rise to values well below the endurance limits of these materials. It is, therefore, desirable to recognize that the size of an induction motor is measured electrically by its breakdown torque, and mechanically by the size of shaft and bearings, the temperature rise being only a secondary factor. Calculations are presented, based on idealized assumptions, which indicate that the optimum temperature rise for continuous rated induction motors is below 80 degrees centigrade, whatever the insulating materials used.

Electric Welding

45-28—Power Supply for A-C Arc Welding; *A. U. Welch (A'36), R. F. Wyer.* *20 cents.* A-c arc welders may be divided into two general types—industrial and utility units. Industrial welders usually have built-in power-factor correction and operate at 0.75 to 0.85 power factor at full load. High-reactance transformer-type arc welders generally draw low inrush currents when energized. Transient overcurrents caused by starting a weld are usually less than 1.5 times the steady-state current. Duty factors run from 10 per cent to 50 or 60 per cent in manual welding, depending on the nature of the work. Diversity drastically reduces the maximum 15-minute demand, when more than four or five units are operating. Utility welders are designed for low kilovolt-ampere input. A suggested design would have a maximum 15-minute demand not exceeding 3.5 kva. A desirable design feature is strict limitation of the maximum obtainable output. A consumer supplied at 230 volts from an individual distribution transformer large enough to handle an electric range would not require additional transformer capacity to handle such a welder.

45-29—Analysis of Arc-Welding Reactors; *C. M. Wheeler.* *15 cents.* The need and use of arc-welding reactors used for stabilizing the characteristics of single-operator d-c arc-welding sets are examined. The inductance useful in stabilizing welding arcs should be defined as the rate of change of flux linkages per ampere. This quantity, "welding inductance," is a function of current for iron-core reactors, one which may be evaluated from saturation curves and oscillographic tests. Through the study of performance requirements and the function of inductance in stabilizing welding arcs, synthesized reactor designs can take full advantage of electromagnetic material. They thus are tailored to the requirements of the user. A new arc-welding reactor embodying the principles of synthesis of design has a unique feature which at the same time improves the transient characteristics of the welding generator and makes possible a substantial reduction in size and weight.

45-48—The Power-Distribution Problem in Arc Welding; *H. W. Pierce, C. E. Smith (A'40).* *20 cents.* The extent to which arc welding has contributed to the metal-fabricating industries in the present war has been well publicized, together with discussions of the problems of product design, materials, and operator training. Less has been written on the problem of power and power distribution in large-scale welding operations. This paper discusses the general principles and factors involved in the selection of power and the method of distribution with emphasis on flexibility to meet changing schedules and an expanding load. The application of these principles is illustrated in the selection of d-c power and a constant-potential distribution system for the ways in a shipyard with both a-c and d-c power from individual machines in the shops. The details of the distribution systems are fully described with illustrations.

Electronics

45-20—Arc-Backs in Rectifier Circuits—Artificial Arc-Back Tests; *R. D. Evans (F'40), A. J. Maslin (A'42).* *30 cents.* This paper presents the results of an extensive investigation of arc-backs in rectifier circuits. The various factors affecting the arc-back current magnitudes and durations are reviewed. The nature of sympathetic arc-backs is discussed. Methods of making artificial arc-back tests are described, and relation to neutral arc-back conditions are compared. Results of extensive artificial arc-back tests made in the laboratory and the field are presented. These arc-back tests provided an opportunity for investigating the possibility of voltage surges, but no important voltage surges were observed.

45-35—Design of Sealed Ignitron Rectifiers for Three-Wire Service; *M. M. Morack (M'42).* *15 cents.* Two-wire sealed ignitron rectifiers in the range of 75- to 1,000-kw capacity, at voltages between 250 and 600 volts direct current, have found wide application in industry during the war years. Rectifiers have met the need for efficient d-c power in general industrial, railway, mining, and electrochemical fields. The field of application is enlarged by the development of equipments for three-wire service, and it is the purpose of this paper to describe the design and operating characteristics of these units.

45-51—Rectifier Fault Currents; *C. C. Herskind (M'40), H. L. Kellogg (A'41).* *20 cents.* The determination of fault currents in rectifier circuits is essential to the co-ordination of rectifiers, transformers, and protective switchgear to obtain the best design as regards economy and reliability. Methods are presented for determining the fault currents which flow in rectifier circuits during d-c short circuits and arc-backs. Three basic types of rectifier faults are considered in the analysis:

1. D-c short circuit.
2. Arc-back in a wye.
3. Arc-back with d-c feed.

Formulas are derived for fault current in these three cases. The analyses treat the general case where the rectifier-transformer secondary windings are interlaced and the reactance in the secondary leads is negligible so that all the circuit reactance may be considered to be located in the transformer primary winding and supply line. Typical oscillographic records of fault-current wave forms are presented together with a comparison of test and calculated values.

45-53—Voltage and Current Relations for Controlled Rectification With Inductive and Generative Loads; *K. P. Puchlowski (A'43).* *25 cents.* The conventional methods of analytical treatment of power rectifiers do not offer any ready means for calculation of current and voltage outputs in the case where the firing point is delayed beyond a certain critical value, a condition very often met with in control systems. In addition the application of controlled rectifiers to d-c motors has created a number of special problems which are not answered by the conventional rectifier theory. This paper presents a generalized outline of analytical relations as well as a method of calculations of average values of steady-state output voltages for a polyphase rectifier system with delayed firing. Two types of load are considered: the *R-L* load and the one which includes a voltage-generating element in addition to *R* and *L* constants. The first type of load is, of course, very typical for various control circuits, since it represents, in general, coils of different control devices and what is of particular importance, field windings or rotating machines. The second type of load is typical in the case of a d-c motor drive, where the

rectified and controlled voltage is applied to the armature of a rotating d-c motor. In addition to general formulas the paper analyzes a number of border conditions of special interest and presents two examples of calculations.

45-62-ACO—Principles of Grid Control for Thyratrons; *P. H. Chin (A '41), E. E. Moyer (M '44). 25 cents.* This paper is intended as a preamble to a study of practical circuits for grid control. of thyratrons. In addition to a detailed discussion of the basic methods of grid control, it includes the control characteristics of thyratróns with an alternating potential applied to the anode. In this paper, basic methods of grid control are classified into three categories:

1. Control by a direct potential.
2. Control by an alternating potential.
3. Control by a combination of direct and alternating potentials.

One-tube elementary circuits are used to illustrate the basic schemes of grid control, together with diagrams of wave forms to describe the successive stages of control actions.

Industrial Power Applications

45-21—Dodge Chicago Plant's Electric-Power-Distribution Scheme With Airplane-Engine-Testing Power Recovery; *E. L. Bailey (F '43). 15 cents.* The paper gives a brief outline of the electrical distribution of light and power for the project with a tabulation showing connected load, load factors, and estimating of kilowatt demand. Different airplane-engine testing equipments then are described, giving a full account of the slip-ring generator used without a slip-type coupling as the unit selected for this plant. A typical engine test cell is shown in a cutaway drawing, with full description in the text. A circuit diagram shows how 60-cycle power is recovered and measured in the stator, with loading resistors for dissipating the slip losses from the rotor. Finally, observations are made regarding the use of series and shunt capacitors for voltage regulation and power-factor correction, along with general comments on the performance of the system.

45-71—Application of Electric Equipment for Propeller Milling Machine; *H. E. Morton, O. G. Rutemiller (M '41). 15 cents.* The propellers used on large vessels are sometimes as much as 24 feet in diameter. Accurate surface contour is necessary for maximum efficiency and minimum erosion. In the past, the surfaces of such propellers have been finished almost entirely by hand, a time-consuming job that does not lend itself to high accuracy. The recently developed Morton ship-propeller milling machine has provided the Naval designers and shipbuilders with a tool that will generate accurately the contours of both sides of a propeller blade simultaneously at a tremendous saving of time and with the elimination of the greater part of the handwork and its inaccuracies. The application of wide-speed-range adjustable-speed d-c motors, a new and unique electric position regulator, and modern full magnetic control have made this machine possible. The primary feed motion is driven by a Rototrol-regulated wide-speed-range drive, which provides easy and accurate control of the operating speeds over a wide range with good speed regulation as well as accurate control over the rates of acceleration and retardation. The position regulators make it possible for the machine to follow the contours of scale models with such a degree of accuracy that amplifications of as much as five to one are possible, and the resultant deviation from the desired contour is much less than heretofore possible. The magnetic control provides for the safety of the operator, the machine, the cutters, and the work. It makes the machine follow an automatic sequence of operations, when the machine is cutting, and provides finger tip control of all motions to facilitate and speed up a rather tedious setting-up operation. This machine is a very good illustration of the potential possibilities of design, when machine designers and electrical equipment designers co-operate fully in the conception and development of an intricate machine.

45-25—The Design of Bus-Bar Industrial Distribution Systems: an Epitomization of Available Data; *T. J. Higgins (A '40). 30 cents.* This paper is written to acquaint the designer of bus-bar industrial distribution systems with the extent and location of the theoretical and experimental data available for design purposes. Attention is confined to those factors that essentially determine the operating characteristics of a bus-bar distribution system: voltage drop, temperature rise, and short-circuit capacity. Epitomization of the pertinent content of 575 apposite references is presented. A guide is provided to most, possibly all, of the consequential literature on the design of bus-bar distribution systems, including many forgotten or little-known papers containing valuable material not to be found elsewhere. As to the practical usefulness of such a guide, it may be said that the designer who acquaints himself with all of the information detailed in the writings mentioned will be enabled:

1. To better his own design procedures.
2. To improve on present bus designs.
3. To forestall costly experimentation undertaken to obtain data either extant—but unknown to those proposing experiment—or possible of calculation from existing theory.

45-72—Application of Capacitors for Power-Factor Improvement of Induction Motors; *W. C. Bloomquist (A '43), W. K. Boice (M '43). 20 cents.* The practice of connecting capacitors at the motor terminals in order to permit switching the capacitors and motor as a unit will not result in adverse motor operation, if the amount of capacitors is properly selected. A few problems to be considered are:

1. Overvoltage due to self-excitation.
2. Transient torques.
3. Overvoltage in current-transformer secondary circuits.
4. Overload protection for the motor.

This paper discusses these problems and explains the necessity of limiting the amount of capacitors to be connected to a motor, when both are switched as a unit. A useful application table is included, listing the maximum capacitor rating for motors and the reduction in line current with the recommended capacitor rating; this latter information is helpful for selecting the proper motor-overload protective device. Information and data are included showing the relative economics of power-factor improvement by capacitors with individual motors and the group-capacitor method.

45-47—Tracer-Controlled Position Regulator for Propeller Milling Machine; *C. R. Hanna (M '39), W. O. Osbon (M '41), R. A. Hartley (A '43). 20 cents.* The position regulator designed to control the ship-propeller milling machine discussed in a companion paper by Mr. Rutemiller and Mr. Morton is described in detail. The regulator makes possible the machining of large propellers in conformity to scale models with speeds and accuracies heretofore unobtainable. It consists essentially of a variable-voltage drive controlled through an amplifier and exciter by a Silverstat tracer unit designed to accommodate propeller-to-model ratios from 2:1 to 5:1. The various circuit arrangements required to stabilize the regulator and to insure accurate following over a wide range of speeds and accelerations are explained. A typical stability calculation is given in the appendix.

45-79—Modern Electric-Power-Distribution Ideas as Applied in a Large War Plant; *R. H. Kaufmann (M '41), N. A. Kieb (M '43). 25 cents.* This paper describes the design and installation of the electric distribution system incorporated in the Kansas City Pratt and Whitney aircraft engine plant involving over 2,000,000 square feet of working area. Conservation of material and time were of paramount importance. An electric system substantially independent of building structure was sought and attained. Modern economical principles of load-center power distribution are applied, using the secondary selective arrangement for service reliability. Features contributing much to over-all economy include:

1. 460/265-volt service in factory areas serving 440-volt polyphase motors and 265-volt fluorescent lighting units.
2. Spaced single-conductor low-voltage feeders of moderate cross section feeding short lengths of 250-ampere plug-in bus.
3. Overhead cable troughs for 13.8-kv feeder cable.
4. Air-pressure cooling of main incoming service transformers.

For the major part, the economies effected in this installation fundamentally are sound and should prove useful in securing more economical power distribution in future industrial plants.

45-80—Induction Heating of Moving Strip; *R. M. Baker (M '40). 30 cents.* Induction heating at frequencies of several hundred kilocycles per second has been used very successfully to melt the surface and brighten electrolytic tin plate at a strip speed of 1,000 feet per minute. This paper gives a complete analysis of the problems of heating moving magnetic strip, and shows when it is necessary to use radio-frequency power and when the heating may be accomplished satisfactorily at rotating machine frequencies (9,600 cycles per second or less).

Instruments and Measurements

45-19—A Modulated-Frequency System of Telemetering; *H. E. Renfro, A. P. Peterson* (*A '32*). *15 cents.* This paper describes the operation of a modulated-frequency system of telemetering, which was developed as a result of an urgent need of the City of Seattle Department of Lighting for a telemetering system which would provide high-speed continuous visual indications. Other requirements were: that the indications be independent of variations in line characteristics and that several indications be transmitted simultaneously over existing telephone pairs without interruption of communication. Modulated frequency, as the transmitted quantity in telemetering, has been used in the past, and this paper is in no way meant to imply that these other schemes have been unsuccessful. The authors believe, however, that the means described of controlling the frequency at the transmitting point and measuring the frequency at the receiving point is unique.

45-24—Orthomagnetic Bushing Current Transformer for Metering; *A. Boyajian* (*F '26*), *G. Camilli* (*F '43*). *15 cents.* If a magnetic core is excited simultaneously at two different frequencies, three interesting phenomena may be observed:

(*a*). The lower-frequency hysteresis loss may be reduced or even wiped out, while the higher-frequency losses are considerably increased.

(*b*). Under certain conditions, there may also be observed a reduction in the lower-frequency exciting current and an increase in the higher-frequency exciting current.

(*c*). If the frequency and the flux density of the higher-frequency excitation are chosen properly and maintained, the lower-frequency volt–ampere excitation curve of the core can be rendered practically a straight line over a wide range of the lower-frequency flux density.

If the lower frequency is the operating frequency of a current transformer, every one of these items is beneficial toward securing greater current-transformer accuracy, item (*c*) being the most important one because it renders the ratio and phase-angle errors constant and, therefore, precise compensations for them possible. Data are furnished on bushing-current transformers of such design for high voltages and low currents with greatly improved accuracy, using triple-frequency auxiliary excitation. Because of item (*c*) the authors have christened the core and the device orthomagnetic.

45-64—An Interval Timer for Arc Duration; *J. S. Quill* (*A '43*). *15 cents.* This paper describes a laboratory instrument which was developed for the purpose of measuring the time in milliseconds that an arc exists when an electric circuit is opened. The instrument uses signals obtained from the arc voltage and circuit current, respectively, to start and to stop a timing circuit, consisting of a capacitor charged linearly with time by the constant current of a pentode. Besides the description of the new instrument, the paper describes how it has been used for the investigation of both a-c and d-c arc interruption and for the accumulation of information on problems relating to arc interruption.

45-65—Dynamic Measurements on Electromagnetic Devices; *E. L. Norton. 25 cents.* The paper describes a method for the point-by-point measurement of the instantaneous value of flux, current, displacement, and velocity of electromagnetic apparatus, such as relays. The time during the cycle of operation may be accurately set, and the readings are made from the steady deflection of a d-c instrument. The apparatus is described in detail, and the results of some typical measurements are given.

45-66—A Portable Instrument for Measuring Insulation Resistance at High Voltage; *F. W. Atkinson* (*M '37*), *R. B. Taylor. 15 cents.* There has been an increasing trend toward measuring insulation resistance of high-voltage machines and cables at or above their rated voltage by the use of direct current. Up to the present the equipment for this type of testing has been large and heavy. The new portable tester described in this paper will stimulate greatly collection of valuable data on insulation testing and insulation resistance throughout the industry. The new instrument—rugged despite its light weight (31 pounds)—was made possible by the development of a new cold-cathode rectifier tube, which also is described. The tester now is being used in the evaluation of aircraft ignition systems. Some exploratory work has been done with it in the industrial field, where its potentialities appear highly promising. Lightweight power supplies and insulation-resistance testers may be designed for voltages up to 200,000 volts or higher.

Land Transportation

45-10—Electrification and Signaling of the Canadian National Railways' Terminal, Montreal, Canada; *R. G. Gage. 15 cents.* The Montreal Terminal was completed in 1943 to co-ordinate existing passenger and develop additional freight facilities to meet wartime traffic. The electrification is an extension of existing 2,400-volt d-c system and is supplied from eight Hewittic glass-bulb rectifier units, the first installation of the kind for traction purposes in Canada. Train operation throughout 12 miles of terminal main track is by signal indication only and is controlled by two electric relay-type interlockers, situated one on each side of the St. Lawrence River. One of these comprises, perhaps, the largest interlocker of its kind, when the area involved is considered. This is made possible by the use of a new high-speed signal code. This centralization of control has resulted in a large reduction in terminal train delays.

45-11—Grounding of Circuits on Self-Propelled Vehicles; *D. D. Ewing* (*F '21*). *15 cents.* There is a lack of standardization and uniform practice, in connection with the grounding of circuits on self-propelled vehicles, such as locomotives and busses, which in some areas now is affecting development. This paper presents a brief survey of current practice and certain conclusions, all prepared with the idea of bringing out constructive criticism and new viewpoints. It is suggested that the Institute sponsor a committee, representing the interested agencies, to develop the desired standards and recommended practices.

45-17—Mercury-Arc Rectifiers for Railroads; *S. S. Watkins* (*M '26*). *15 cents.* Present status and design trends are examined for their significance in design of d-c power supply for electric traction. Maintenance cost of rectifiers on railroad load is found to be about half that of synchronous converters. Estimated space and cost are presented for substations using present-day rectifiers. Rectifier groups of 36 or more phases have been used in electrochemical industry, but 6-phase and 12-phase rectifiers have been satisfactory in railroad service. Recent mass production has stimulated design improvement of single-anode rectifiers. For 650-volt railroad load new manufacture of multi-anode rectifiers is not expected. For 3,000-volt service both single-anode and multi-anode rectifiers now are obtainable. Sealed steel-tube rectifier substations are suggested for 600-volt trolley-coach systems. Anode circuit breakers have widened the choice of high-speed switching for railroad substations. Grid control and ignitor timing are methods available for limiting rectifier load or for producing compound characteristics.

45-31—Compressed-Air Circuit Breakers in A-C Railway Service; *H. M. Wilcox* (*M '27*), *D. C. Harker* (*A '38*). *15 cents.* The increasing interest in compressed air as an interrupting and operating medium for circuit breakers in central-station and industrial service, together with its gratifying record in service periods extending up to five years, warrant investigation of its application to a-c railway service. Previous developments leading up to present standards of requirement for this service are reviewed, and a description is given of a compressed-air circuit breaker designed for high-speed interruption of short circuits on contact-line feeders in single-phase 25-cycle railways service at 12,000 volts to ground. Application of the principle to other railway service is discussed.

Power Generation

45-34—Frequency Changers—Characteristics, Applications, and Economics; *S. B. Crary* (*M '37*), *R. M. Easley. 25 cents.* This paper deals with frequency changers for interconnected power systems of different frequencies. The characteristics of synchronous and nonsynchronous ties are discussed followed by a brief description of the essential performance characteristics of five different types of frequency changers. Attention is given particularly to the requirements for the important steel-mill and railroad-electrification applications. Included is an economic discussion which presents relative costs and losses. It is concluded that the synchronous–synchronous type of frequency changer is best suited for supplying power for low-frequency railroad electrification, whereas the induction–synchronous load-regulating and the electronic load-regulating frequency changers best meet the requirements for confining objectionable load changes to the system where they originate.

45-36—Proposed Preferred Standards for Large 3,600-Rpm Three-Phase 60-Cycle Condensing Turbogenerators; *AIEE–ASME Joint Committee on Turbogenerators. 20 cents.* Recommendations for preferred ratings of large turbogenerators have been presented in this report. Six ratings are proposed instead of the present 11 ratings.

Steam conditions and electrical rating characteristics are standardized. In addition, the AIEE group has recommended standard specifications for the generators. It is expected that adoption of the proposed standards will reduce costs relative to present-day values and also shorten delivery time. It is expected that standardization of the turbogenerators will not stifle development but should make available more effort for research and improvement.

Power Transmission and Distribution

45-13—Improving Stability by Rapid Closing of Bus-Tie Switches; *E. W. Kimbark (M '35). 15 cents.* Intermediate busses on a double-circuit line are detrimental to stability during the existence of a fault but are beneficial after clearing. Therefore it is proposed to use bus-tie switches which are initially open but which close simultaneously with the opening of the line breakers soon after a fault occurs. Calculations on a particular system, consisting of a hydroelectric station transmitting over a high-voltage double-circuit line to a large receiving system, show that the power limit (based on nine-cycle clearing of a two-wire-to-ground fault at the sending end) is raised 12 per cent by rapid closing of high-voltage bus ties at both ends. This increase is greater than that obtainable through high-speed reclosure and equals the gain obtainable through going to six-cycle clearing. Unlike reclosing, the proposed switching is beneficial with permanent faults or with sequential clearing.

45-18—Lightning Investigation on 132-Kv System of American Gas and Electric Company; *I. W. Gross (M '40), G. D. Lippert (A '38). 15 cents.* The results of a field investigation of lightning effects on parts of an extensive 132-kv transmission system, covering the past five years' records, is presented and discussed. Although the investigation was centered largely near the stations rather than out on the line itself, a few records are included from line towers where lightning currents were measured in tower structures, counterpoises, and ground rods. The magnitude of lightning currents at stations ranged from 2,400 to 11,500 amperes in line conductors; from 1,700 to 10,300 amperes in ground wires; and from 500 to 4,100 amperes in arresters located at stations. The first figure in each case above is the median value observed and the second figure the maximum value. The effectiveness of arresters in holding surge voltages to predetermined values is indicated by the data presented. One feature of the investigation was centered around the determination of rates of surge voltage change at the station entrance and within the station. These records showed that the median value was 220 kv per microsecond, and the maximum value was 810 kv per microsecond for lightning surges. The switching surge voltages at the same location ranged from a median value of 70 kv per microsecond to a maximum of 468 kv per microsecond. The effectiveness of multiple circuits emanating from a station in reducing the severity of lightning at the station itself is discussed, and data are presented thereon. In locations where the soil resistivity is fairly high and the soil a sandy loam, it is found that long ground rods ranging up to 120 feet in length are considerably more effective than buried counterpoises of 250 feet in length. Other comparisons of the effectiveness of counterpoises, ground rods, and tower footings also are presented and discussed.

45-26—Lightning Investigation on Transmission Lines—VIII; *W. W. Lewis (F '38), C. M. Foust (M '31). 30 cents.* Previous papers of this series gave data on a lightning investigation carried on co-operatively by a number of power companies and the General Electric Company, and the seventh paper of the series brought the data up to and including 1938. Additional papers covered special angles of the investigation. The present paper discusses an investigation under the joint sponsorship of the American Gas and Electric Service Corporation of voltages, currents, and rates of change of voltage at five stations of the Appalachian Electric Power Company in Virginia; information on currents in towers and strokes on the lines of five different power companies; and some additional data on the distribution of current in counterpoise wires and driven rods, and voltage gradient near towers on the Consumers Power Company system in Michigan.

45-60—Galvanic Corrosiveness of Soil Waters; *H. S. Phelps (A '21), Frank Kahn (A '36). 15 cents.* Results are presented of a study of relation of *pH* of soil waters to galvanic action between couples of lead, copper, iron, and carbon. Galvanic cell tests were made using as electrolytes actual soil waters or soil extracts from 31 locations at which trouble had been experienced. The following conclusions apparently can be drawn:

1. Galvanic corrosiveness on lead, copper and iron appears generally more severe for soil waters of low *pH* than for those of high *pH*.

2. Indications are that static potentials of lead and iron are practically constant in soil electrolytes of *pH* up to approximately ten. As *pH* is increased above ten, lead becomes more negative and iron more positive. The potential of copper becomes more negative in substantially straight-line relation with increasing *pH*.

3. For electrodes of lead, copper, iron, and carbon in soil waters, a relation between degree of polarization and *pH* of electrolyte is indicated.

45-58—The Dielectric Strength and Life of Impregnated Paper—IV; *J. B. Whitehead (F '12), J. M. Kopper (M '43). 25 cents.* High-stress short-time tests of cable-type impregnated-paper insulation show that a higher-density paper has a lower breakdown strength. The results confirm those of earlier tests in which a step-voltage test over longer times was used. The behavior is much the same for both a light and a heavy oil. A method is described for detecting the first occurrence of gaseous ionization in impregnated-paper insulation and for taking a continuous record of its growth up to breakdown. Interruptions of the tests at various stages as revealed by the ionization recorder show that ionization and failure almost invariably begin in the oil channels and that a time element enters in both pre-ionization and subsequent ionization periods. The mechanism of breakdown, power factor, and capacitance variation as related to paper density are discussed and explained in terms of fundamental conductance phenomena in insulating oils.

45-59—Electrolysis and Corrosion of Underground Power-System Cables; *L. J. Gorman (M '30). 25 cents.* The paper presents a summary of the principles and methods used for the mitigation of electrolysis and corrosion on the underground-cable system of the Consolidated Edison Company of New York, Inc. The test procedures used for stray-current electrolysis are not suitable for the electrolytic types of corrosion. A duct survey has been developed which replaced the manhole tests formerly used for stray-current electrolysis investigations. The procedure for making the duct survey is described. The methods used for the analysis of duct survey data are presented together with the results obtained on the system over a period of approximately four years. The classification of corrosion used by the Consolidated Edison Company is presented together with its application to the corrosion failures experienced on the cable system over a four-year period. The measures used for the mitigation of cable-sheath corrosion are discussed briefly, including electrolysis drainage, cathodic protection, protective covering, cable grease protection, and use of zinc for cathodic protection.

45-61—Study of A-C Sheath Currents and Their Effect on Lead-Cable Sheath Corrosion; *C. M. Sherer (A '39), K. J. Granbois (A '31). 15 cents.* Destruction of lead sheaths on underground cables by corrosion usually can be attributed to stray direct currents, the proximity of dissimilar metals, or direct potentials resulting from unfavorable soil or duct conditions. Alternating current generally has been considered a relatively unimportant factor in corrosion. This paper discusses two cases of insulation failures on single-conductor power cables resulting from sheath corrosion and describes field observations and laboratory tests which indicate that the corrosive action was accelerated greatly at first by rectified alternating currents induced in the sheaths by the load current. Experiments show that lead, when placed with copper in water removed from cable ducts, rectifies alternating current. The rectified current initially is in the direction to make lead anodic and produces corrosion; later a reversal of polarity takes place and lead becomes cathodic. A method of controlling such corrosion is described.

45-67—Impedances Seen by Relays During Power Swings With and Without Faults; *Edith Clarke (M '33). 30 cents.* The paper reviews briefly the work previously done in determining the performance of distance relays during power swings by means of impedance charts and extends this work to include any three-phase system which can be replaced during power swings by two equivalent synchronous machines with balanced generated voltages connected by a symmetrical three-phase linear network in which positive- and negative-sequence impedance can be assumed equal. Power swings during all types of unsymmetrical faults, as well as during symmetrical system conditions, are considered. For the convenience of the busy engineer, the paper is divided into three parts. The development of the method of constructing system impedance charts from equations in specified form in part II and the derivation of these equations in part III are necessarily complex; but the

actual construction of an impedance chart, explained and illustrated in part I, requires very little effort. By the adaptation of a general impedance chart, the behavior of distance relays on a given system can be quickly determined, and, more important, relays having characteristics best suited to a specific application can be selected.

45-77—The Combination of Supervisory Control With Other Functions on Power-Line Carrier Channels; *R. C. Cheek (A '42), W. A. Derr (A '43). 15 cents.* The use of a single-carrier channel to perform several different functions is becoming increasingly common. This practice is encouraged by considerations of economy of equipment and conservation of space in the carrier-frequency spectrum. The requirements of carrier-relaying, telemetering, communication, and load-control systems are generally well understood, and the combination of two or more of these functions on a single-carrier channel is relatively straightforward. However, the channel requirements of supervisory-control systems are not so well known, and the combination of supervisory control with one or more other functions on a carrier channel requires an understanding of the limitations involved. In this paper the carrier-channel requirements of a standard supervisory-control system are discussed, and methods of combining supervisory control with one or more other functions are given. These methods include both the single-station and the multistation types of supervisory control.

45-78—Power-Line Carrier Channels; *M. J. Brown (A '37). 20 cents.* The attenuation of high-frequency currents in power-line carrier channels is discussed from the theoretical viewpoint, and the experience with losses actually encountered is compared with theoretical conclusions. The operating conditions where coupling-capacitor losses are important are outlined. Curves indicating losses through carrier-current line traps are presented.

Protective Devices

45-37—Temperature Limits and Abstracts of Present Standards and Practices for Stationary-Contact Surfaces; *AIEE subcommittee on conduction in stationary contact surfaces. 15 cents.* This paper covers a survey of the present standards of the AIEE, National Electrical Manufacturers Association and Underwriters' Laboratories on the permissible temperature rises of various types of stationary-contact assemblies. A table comparing these limits is given together with abstracts of the Standards dealing with contact temperatures. Wartime standards are mentioned but are not included in the table or in abstract form.

45-43—Field Tests and Performance on Heavy-Duty High-Speed 138-Kv Circuit Breakers—Oil and Air-Blast; *Philip Sporn (F '30), H. P. St. Clair (F '44). 30 cents.* The heavy expansion brought about on the Central system of the American Gas and Electric Company in response to demands for power during the defense and war periods has produced a requirement for circuit-breaker rupturing duties close to 3,500 megavolt-amperes. In order to test the interrupting performance and reliability of two types of 138-kv 3,500-megavolt-amperes circuit breakers—the first an oil, the second an air-blast design—and also to explore faster reclosing cycles than now are offered by the most improved oil circuit breakers, high-capacity field tests were carried out at the Philo plant of the Ohio Power Company. In these tests, involving 20 interruptions on each breaker, successful interruption of a full three-phase short circuit of 3,500 megavolt-amperes with three-cycle interruption and with 13-cycle reclosure has been accomplished for the first time. The results of these tests, it is believed, indicate that a goal of 5,000 megavolt-amperes with 12-cycle reclosure is definitely attainable.

45-44—A Three-Cycle 3,500-Megavolt-Ampere Air-Blast Circuit Breaker for 138,000-Volt Service; *H. L. Byrd (A '43), B. S. Beall, III (A '41). 15 cents.* The latest development in outdoor air-blast circuit breakers has been a three-cycle, 138-kv air-blast circuit breaker having an interrupting rating of 3,500 megavolt-amperes. This breaker has undergone extensive laboratory test and was proved entirely satisfactory in its ability both to handle the high currents which correspond to the megavolt-ampere interrupting rating and to have a comfortable margin on its interrupting time of three cycles. Because of the desire for high-speed reclosing, this breaker was set up to have a reclosing time of approximately 14 cycles, and it has operated successfully under this severe duty. At the completion of laboratory tests, this breaker was submitted for field tests under actual operating conditions and performed with entire satisfaction under all conditions up to 3,500,000 kva. Ultrahigh-speed reclosing operations also were made under actual field conditions up to 3,500,000 kva, the highest power concentrated to date in such tests. This paper describes the theory of operation, the construction, and some of the interesting data which were obtained during development and test of this air-blast circuit breaker.

45-45—A High-Capacity High-Voltage Three-Cycle Oil Circuit Breaker; *H. L. Byrd (A '43), E. B. Rietz (A '42). 15 cents.* This paper describes the development of a high-voltage high-speed oil circuit breaker to meet three-cycle performance up to 3,500,000 kva at 138 kv. The important design features of the interrupting contacts and operating mechanism are reviewed. There is a description of the laboratory testing methods used to predict accurately the performance which was subsequently demonstrated during the highest-capacity field tests on record.

45-46—The Next Step in Interrupting Capacity—5,000,000 Kva; *A. W. Hill (M '41), W. M. Leeds (M '38). 20 cents.* Serious consideration is being given to large power-system interconnections which could develop short circuits at certain locations in excess of 3,500,000 kva. High-voltage oil-circuit-breaker capabilities for such heavy duty are reviewed in this paper, the fundamental design requirements outlined, and results of high-power laboratory tests presented which demonstrate that interrupting capacity ratings as high as 5,000,000 kva are feasible. Laboratory test methods for demonstrating these extremely high arc-rupturing ratings are evaluated. The importance of verifying high-speed reclosing performance with high-power tests is emphasized, and on the basis of data already obtained standard reclosing-time intervals considerably less than 20 cycles are foreseen.

45-52—Anode-Circuit-Breaker Design and Performance Criteria; *E. W. Boehne (F '43). 25 cents.* At the time of arc-back in a mercury-arc rectifier, following the conducting period, an effective asymmetrical alternating voltage generates a unidirectional current which is void of natural current zeros. The first duty of the anode breaker is to develop a counter current which neutralizes this arc-back current, thus creating a current zero. This can be accomplished only by developing sufficient arc voltage in the anode breaker. The effect of the shape of the arc-voltage characteristic of the anode breaker and its time of introduction into the circuit are described on a quantitative basis which reveals the relative magnitude of the peak arc current, arc energy, and the location of the current zero with respect to inverse voltage of the rectifier. Several new and interesting features are revealed. The effect of rectifier drop and circuit resistance are included in the analysis. The essential design features of the *AG-2* high-speed anode circuit breaker are presented together with oscillographic verification of its performance on large industrial circuits having rates of rise of current in excess of 10,000,000 amperes per second.

45-54—Improved Fault Protection for Rural Distribution Systems; *A. Van Ryan (A '44). 15 cents.* This paper describes an improved oil circuit recloser which has been designed to reduce the number of outages on rural distribution systems. Automatic oil circuit reclosers now in use are limited in application because of their inability to co-ordinate properly with fuse links on the load side of the recloser. This new automatic oil circuit recloser incorporates the advantages of fast opening on the first and second operations to clear all transient faults on the protected section and of operating with time delay on the third and fourth operations to permit the sectionalizing fuse to blow, and thus it isolates a permanent fault without causing a lockout of the recloser.

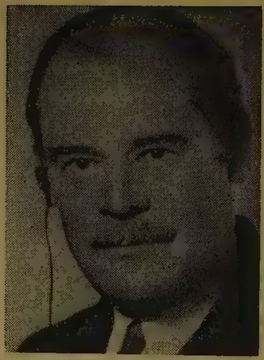
45-55—Rectifier Relay for Transformer Protection; *E. L. Michelson (M '44). 15 cents.* In differential protection of transformers, the effect of inrush currents plays an important part. This current is equivalent to fault current and tends to operate a differential relay. This paper describes various methods that have been used to eliminate the effect of inrush currents and particularly describes a new relay for this purpose. The new relay uses dry-type rectifiers and separates the differential current into its positive and negative components. In the case of inrush currents, the current is predominately of one polarity, and the relay will not trip. Under fault conditions, currents of both polarities appear and cause tripping of the relay. The paper describes the construction of the relay, laboratory tests, and an actual installation.

45-56—New Solenoid Mechanism for Magne-Blast Breakers; *B. W. Wyman (A '40), J. H. Keagy (A '42). 25 cents.* When a circuit breaker is closed in upon a short circuit, the closing motion is retarded by high magnetic forces at the time the fault current is initiated. These retarding forces increase as the square of the fault current. If the fault current be sufficiently high, these forces may stall completely or, even more seriously, slowly reverse the closing motion. The result is severe arcing and disturbance within the breaker, until it is tripped. In some mechanisms this condition often is aggravated by subnormal control voltage at the coil terminals, which further reduces the ability of the mechanism to close the breaker. This paper describes a solenoid mechanism design used for operating the Magne-blast circuit breaker, which is effective in closing the breaker against short-circuit currents as high as 80,000 amperes without damage to the breaker contacts. The departure from the conventional magnetic circuits of the solenoid responsible for this superior closing performance also minimizes the effect of subnormal control voltage.

45-57—Nine Years Experience With Ultra-high-Speed Reclosing of High-Voltage Transmission Lines; *Philip Sporn (F '30) C. A. Muller (M '36). 15 cents.* Data covering nine years' operating experience with 91 ultrahigh-speed-reclosing circuit breaker installations mainly on a large interconnected and integrated high-voltage system are presented and analyzed: out of 635 cases of flashover cited, 570 reclosures were successful and 65 cases of reclosure were unsuccessful, a record of 89.8 per cent successful reclosure. Double-circuit lines show a record of unsuccessful reclosure double the average, but 80 per cent of the apparently unsuccessful reclosures resulted in successful reclosure of one circuit. The conclusions drawn are that ultrarapid reclosure has proved itself a tool of major importance for use in improving high-voltage-line reliability; that its use can, and should be, extended to lower-voltage lines; and that further improvements are in sight as a result of recent improvements in circuit-breaker opening and reclosure time.

PERSONAL ....

W. R. Wilson



E. F. W. Alexanderson

E. F. W. Alexanderson (A '04, M '13, F '20) consulting engineer, General Electric Company, Schenectady, N. Y., has been awarded the Edison Medal for 1944 "for his outstanding inventions and developments in the radio, transportation, marine, and power fields." Doctor Alexanderson, the 34th recipient of the medal, was born on January 25, 1878, in Upsala, Sweden. He was graduated from the Royal Institute of Technology, Stockholm, in 1900 and has been awarded honorary degrees by Union College (1926) and by the Royal University of Upsala (1938). Doctor Alexanderson came to the United States in 1901, entered the General Electric Company in 1902 as draft man, and in 1904 transferred to the engineering department. From 1919 to 1924 he was also chief engineer of the Radio Corporation of America for whom he superintended the construction of powerful radio stations in Sweden, Poland, England, Hawaii, California, and on Long Island. He was a pioneer in television and the first home reception of television took place in his home in 1927. His other contributions to radio include the Alexanderson high-frequency alternator, multiple-tuned antenna, vacuum-tube radiotelephone transmitter, and tuned-radio-frequency receiver, and, in addition, he holds many patents in the power and control fields. Doctor Alexanderson is a past president of the Institute of Radio Engineers and a member of the Royal Academy of Science, Sweden. Among other honors he has received the Order of the North Star, Sweden; the Order of Polonia Restituta, Poland; the Gold Medal of the Institute of Radio Engineers; and the John Ericsson Medal.

C. L. Collens (A '07, M '40) president of the Reliance Electric and Engineering Company, Cleveland, Ohio, has been elected to the newly created post of chairman of the board. Mr. Collens is a graduate of Yale University (1896) and Columbia University (1897) In 1897 he joined the staff of the Hartford Electric Light Company, Hartford, Conn.; in 1899 he was with the International Acheson Graphite Company, Niagara Falls, N. Y.; and in 1906 with the Niagara Power Company, Niagara Falls. Mr. Collens has been president of the Reliance Electric and Engineering Company since 1907. **A. M. MacCutcheon** (A '12, F '26) engineering vice-president, has been elected senior vice-president. Mr. MacCutcheon was graduated from Columbia University in 1908. He joined the Reliance Electric and Engineering Company in 1914 and was made engineering vice-president in 1923. He is a past president of AIEE.

W. R. Wilson (A '43) General Electric Company, Pittsfield, Mass., has been awarded the Alfred Noble Prize for 1944 for his paper, "Corona in Aircraft Electric Systems as a Function of Altitude" (AIEE *Transactions*, volume 63, 1944, April section, pages 189–94). Mr. Wilson was born on May 3, 1919, in South Bend, Ind. In 1941 he was graduated from the University of Michigan with the degree of bachelor of science in engineering physics. Following his graduation, Mr. Wilson became an assistant in the research laboratory of the General Electric Company, Schenectady, N. Y. In 1942 he transferred to the Pittsfield, Mass., works of the General Electric Company as an engineer's assistant. The Alfred Noble Prize was instituted in 1929, and the selection of Mr. Wilson as 1944 recipient brings the award to AIEE for the seventh time.

R. R. Robertson (M '25) chief electrical engineer and deputy general manager, Los Angeles (Calif.) Department of Water and Power, has retired. Mr. Robertson, a graduate of Purdue University (1907) began his career in 1907 as a mechanical draftsman for the Isthmian Canal Commission, Panama. He was employed by them until 1912 when he entered the employ of the Los Angeles Bureau of Power and Light. After service in the United States Army during the first World War, Mr. Robertson returned to the Bureau of Power and Light as construction superintendent. By 1940 he had become head of the division and when the water and power bureaus were merged in November 1943 he became chief electrical engineer and deputy general manager of the Department of Water and Power.

J. E. Hobson (A '36, M '41) director of the school of engineering, Illinois Institute of Technology, Chicago, has been appointed director of the Armour Research Foundation. Doctor Hobson was graduated from Purdue University in 1932 with a bachelor-of-science degree, received his master's degree in 1933, and his doctor-of-philosophy degree from the California Institute of Technology in 1935. In 1936 he taught in the electrical-engineering department of the Illinois Institute of Technology, leaving in 1937 to work for the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. He returned to the Illinois Institute of Technology as head of the electrical-engineering department in 1941.

Victor Siegfried (A '32, M '38) assistant professor of electrical engineering, Worcester (Mass.) Polytechnic Institute, has been appointed chief research engineer, electric cable works, the American Steel and Wire Company, Worcester. Mr. Siegfried was graduated from Stanford University in 1930 with a bachelor-of-arts degree, and in 1932 he received a degree in electrical engineering. In 1933 he became an instructor in electrical engineering at the Worcester Polytechnic Institute, and in 1937 Mr. Siegfried was appointed assistant professor.

Wallace Montgomery (A '25, M '28) formerly production manager, the G. Washington Coffee Company, Morris Plains, N. J., has been elected vice-president in charge of production. A graduate of Tulane University in 1913, Mr. Montgomery's first position was with the American Beet Sugar Company, Oxnard, Calif. From 1913 through 1926 he held engineering and managerial positions in Mexico and Cuba and subsequently established his own business as consulting engineer in San Diego, Calif. Mr. Montgomery joined the G. Washington Coffee Company in 1927.

Thomas Ingledow (M '41) chief engineer, British Columbia Electric Railway Company, Ltd., Vancouver, British Columbia, Canada, has been made vice-president and chief engineer of the electrical department. Mr. Ingledow was graduated from Glasgow University, Scotland, in 1922 and attended the Royal College of Science in London until 1923. In 1925 he became a design engineer for Montreal (Quebec) Light, Heat and Power Consolidated and in 1940 he joined the British Columbia Electric Railway Company.

J. W. Milnor (A '13, F '30) consulting engineer, Western Union Telegraph Company, New York, N. Y., retired on October 1, 1944. Mr. Milnor was graduated from Lehigh University in 1912. Following his graduation he became an assistant in the laboratory, General Electric Company, Pittsfield, Mass. He entered the employ of Western Union Company in 1913 as engineering assistant, becoming research engineer in 1919, transmission engineer in 1936, and consulting engineer in 1943.

W. M. Gifford (A '18) general sales manager, Aluminum Company of Canada, Toronto, Ontario, retired on September 28, 1944, to assume special duties in connection with the president's office. Mr. Gifford has been with the Aluminum Company of Canada since 1927. Previously he had been employed by the Northern Aluminum Company, Ltd., Toronto, which he joined in 1910 as salesman. His retirement comes on the anniversary of his 40th year in the aluminum industry.

H. R. Searing (A '20, F '30) vice-president, Consolidated Edison Company, New York, N. Y., has been elected a trustee and a member of the executive committee of that company. He has also been elected a director of the New York and Queens Electric Light and Power Company, the Westchester Lighting Company, and the New York Steam Corporation, all of New York.

Lee de Forest (A '04, F '18) director of research, Lee de Forest Laboratories, Los Angeles, Calif., has been active in the organization of a center for electronic research, a factory for the production of radio and television equipment, and a commercial radio station, all in Mexico, Federal District, Mexico.

F. R. Innes (A '25, M '26) managing editor, *Electrical World*, New York, N. Y., has been made associate editor to take charge of expanded treatment of public utilities. He joined the staff in 1925, was made western editor at Chicago, Ill., in 1926, and was appointed managing editor in 1939.

C. F. Kettering (A '04, F '14) vice-president in charge of research, General Motors Corporation, Dayton, Ohio, has been made a member of the subcommittee on applied cyclotronics of the postwar program committee of the State of Ohio.

W. E. Mitchell (A '06, F '22) vice-president and general manager, Georgia Power Company, Atlanta, has been appointed by the United States Chamber of Commerce to its Natural Resources Department committee for 1944–45.

Robin Beach (A '15, F '35) professor and head of the department of electrical engineering, Polytechnic Institute of Brooklyn, N. Y., has organized the firm of Robin Beach Engineers Associated, consulting engineers, Brooklyn.

A. C. Streamer (A '19, M '41) vice-president Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been elected president of the National Electrical Manufacturers Association.

J. B. Clapp (A '24, M '36) sales engineer, James P. Kearny Corporation, New York, N. Y., has joined the Thomas and Betts Company, Elizabeth, N. J., as their special representative in the utility field.

R. P. M. Carmody (A '24) manufacturers' representative, Buffalo, N. Y., has been appointed sales representative in the Buffalo area for the storage battery division of the Philco Corporation.

M. S. Coover (A '16, F '42) professor and head of the department of electrical engineering of the Iowa State College, Ames, has been elected president of the Iowa Engineering Society for 1944–45.

F. R. Lack (M '37) vice-president and manager of the radio division of the Western Electric Company, New York, N. Y., has been elected a director of the Radio Manufacturers Association.

George Hamburger III (A '44) formerly application engineer for the Delta Star Electric Company, Chicago, Ill., will be in charge of the new office of the Copperweld Steel Company, St. Louis, Mo.

Ernst Weber (A '31, F '34) research professor of electrical engineering, Polytechnic Institute of Brooklyn, N. Y., has been elected second vice-president of the New York Electrical Society.

J. E. Sheehan (M '28, F '33) formerly sales engineer, Line Material Company, South Milwaukee, Wis., has been appointed manager of the transformer sales department, Zanesville, Ohio.

W. L. Abbott (A '01, F '13) retired chief operating engineer of the Commonwealth Edison Company, Chicago, Ill., has been made an honorary member of the Chicago Engineers Club.

A. J. Cooper (A '24) assistant manager of the New York district, Allis-Chalmers Manufacturing Company, has been elected president of the Montclair (N. J.) Society of Engineers.

P. R. Plant (A '26) now serving with the United States Naval Reserve at the Naval Boiler and Turbine Laboratory, Philadelphia (Pa.) Navy Yard, has been promoted to the rank of lieutenant commander.

C. E. Tarwater (A '40) operating engineer of the Knoxville (Tenn.) Electric Power and Water Board, will become, in addition to his other duties, acting superintendent of the Board.

L. V. Sutton (A '11, M '38) president of the Carolina Power and Light Company, Raleigh, N. C., has been awarded the honorary degree of doctor of engineering by North Carolina State College.

C. M. Mackey (A '34, M '36) formerly branch manager, Westinghouse Electric Supply Company, Houston, Texas, has been transferred to Dallas as Southwestern district manager.

E. E. Kinney (A '27, M '41) formerly associate professor of electrical engineering, Michigan State College, East Lansing, has been named superintendent of buildings and utilities.

F. E. Bell (M '35) formerly chief engineer, office of war utilities, War Production Board, Washington, D. C., has joined the Maxon Construction Company, Inc., Dayton, Ohio.

F. H. Searight (A '38) acting district manager, the Allis-Chalmers Manufacturing Company, San Francisco, Calif., has been appointed district manager.

David Sussin (A '33) chief engineer, the Kelley-Koett Manufacturing Company, Covington, Ky., has been appointed chief of research.

W. C. Fowler (A '30, M '36) sales engineer, Sangamo Electric Company of Springfield, Ill., at Fort Worth, Tex., has been elected president of the Fort Worth Electronics Club.

A. W. Howell (A '36) engineer, operating division, Union Electric Company, St. Louis, Mo., has been named power supervisor.

T. W. Hill (A '39) now with the British War Office in New York, N. Y., will return to Canada and his editorial post with *Electrical News and Engineering*, Toronto, Ontario.

H. L. Olesen (M '27) assistant sales manager, Weston Electrical Instrument Corporation, Newark, N. J., has been promoted to the position of sales promotion manager.

F. E. Anderson (A '31) major, United States Army Engineers, Sacramento, Calif., has been promoted to the rank of lieutenant colonel.

A. W. Howell (A '36) engineer in the operating division, Union Electric Company of Missouri, St. Louis, has been named power supervisor of that company.

Rolf Selquist (A '25) electrical engineer, Copperweld Steel Corporation, Glassport, Pa., has been appointed consulting engineer.

OBITUARY • • • •

Charles Felton Scott (A '92, F '25, HM '29) professor of electrical engineering emeritus, Yale University, New Haven, Conn., and past president of AIEE, died December 17, 1944. Doctor Scott was born on September 19, 1864, in Athens County, Ohio. He was graduated from Ohio State University in 1885 with the degree of bachelor of arts and for a year and a half took postgraduate courses at Johns Hopkins University. Doctor Scott began his electrical career as a wireman for the Baldwin Locomotive Works. In 1888 he entered the employ of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., as night assistant in the testing room. In 1891 he became assistant electrician, in 1897 chief electrician, and in 1904 consulting engineer. In the Westinghouse laboratories Doctor Scott assisted Nikola Tesla in the development of the polyphase induction motor. He was with the Westinghouse Company until 1911 when he accepted the professorship of electrical engineering at the Sheffield Scientific School, Yale University. He retired from active professional duties in 1933. Doctor Scott distinguished himself in the field of engineering as well as that of education. He was the inventor (1894) of the Scott "T" connection by which static transformers are arranged to change two-phase alternating current to three-phase and vice versa. Under his administration as AIEE president (1902–3) Section growth was stimulated, the high-voltage transmission committee was founded, and Student Branches were established. As president, Doctor Scott advocated that the plans for a building for the Institute be extended to include other engineering societies and he was instrumental in interesting Andrew Carnegie who subsequently donated $1,500,000 for the building. In 1902 Doctor Scott was president of the Engineers' Society of Western Pennsylvania and in 1904, at the International Electrical Congress at St. Louis, Mo., he was chairman of the power-transmission section. During 1921–23 he was president of the Society for the Promotion of Engineering Education. In 1935 Doctor Scott was elected chairman of the Engineers Council for Professional Development and in 1936 an honorary member of the Connecticut Society of Civil Engineers. He was vice-president of the National Council of State Boards of Engineering Examiners in 1937 and president in 1938. He was a charter member of the United Engineering Society and also a member of the American Society of Mechanical Engineers and the Illuminating Engineering Society. Doctor Scott was the AIEE Edison Medalist for 1929, and in 1930 he was the recipient of the Lamme Medal awarded by the Society for the Promotion of Engineering Education. During the course of his career, he also received many honorary degrees including the degree of master of arts, Yale University; doctor of science, University of Pittsburgh; and doctor of engineering, Stevens Institute of Technology. On the occasion of Doctor Scott's 75th birthday, September 19, 1939, a testimonial dinner sponsored by the AIEE Connecticut Section was held in New Haven which was attended by representatives of national and local organizations. During 1939 and 1940, many AIEE Student Branches held "Scott diamond jubilee" programs in recognition of Doctor Scott's attainments and special position as founder of the Student Branch. A more comprehensive biography of Doctor Scott appeared in the September 1940 issue of *Electrical Engineering*, pages 349–53.

Francis A. Hubbard (M '23) development engineer, Bell Telephone Laboratories, New York N. Y., died Nov. 6, 1944. Mr. Hubbard was born on April 1, 1890, in Cambridge, Mass., and in 1911 was graduated from Harvard University with a bachelor-of-science degree. He received his degree of master of electrical engineering in 1914. In 1915 he entered the engineering department of the Western Electric Company, New York, N. Y., and, when the company's foreign business was sold to the International Telephone and Telegraph Company, Mr. Hubbard joined its subsidiary, the International Standard Electric Company. As transmission engineer he laid out the Stockholm–Goteborg telephone cable (1920) and the cable connecting Milan, Turin, and Genoa (1922). He returned to the United States in 1930 as transmission engineer for the American Telephone and Telegraph Company and in 1934 transferred to Bell Laboratories as switching research engineer.

H. Linton Reber (A '03, F '13) consulting engineer, St. Louis, Mo., died November 1, 1944. Mr. Reber was born in St. Louis on August 18, 1870, and was graduated from Washington University in 1893 as a civil engineer. His first position was as draftsman for the St. Louis Water Works in 1893. From 1899 to 1922, following sundry engineering jobs, he was chief engineer, general manager, and president of the several telephone companies comprising the Kinloch Telephone system, St. Louis. Also, at times, he was engaged in consultation, designing, and construction of other engineering work. Mr. Reber had been a consulting engineer in St. Louis since 1924. He was a life member of AIEE and a member of the St. Louis Institute of Consulting Engineers, the Engineer's Club of St. Louis, the American Society of Civil Engineers, and the Academy of Science of St. Louis.

Sven R. Bergman (A '04) consulting engineer, River Works, General Electric Company, Lynn, Mass., died November 25, 1944. Mr. Bergman was born on May 23, 1877, in Stockholm, Sweden, and was a graduate of the Royal Institute of Technology, Stockholm. He came to the United States in 1902 and in the same year obtained a position with the General Electric Company in the testing department. During Mr. Bergman's 42 years with the company he worked with both Charles Steinmetz and Elihu Thomson. Since the outbreak of the war he had been specializing in generating equipment for aircraft. Mr. Bergman held many patents on electric machinery. He was the recipient of the Silver Medal at the Panama Pacific International Exposition, San Francisco, Calif., in 1915 and the "Certificate of Merit of the Charles A. Coffin Foundation" in 1934.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting on November 21, 1944, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Dyer, G. A., outside plant engr., Southwestern Bell Tel. Co., Dallas, Texas.
Musgrove, A. M., Lt. Col., Corps of Engineers, U. S. Army, Camp Shanks, N. Y.
Nethercut, D. W., elec. engr., The Ohio Public Service Co., Elyria, Ohio.
Page, G. I., chief operating engr., Public Service Co. of Oklahoma, Lawton, Okla.
Riggs, A. F., district engr., General Elec. Co., Chicago, Ill.
Robertson, E. B., president, Plastics Mfg. Co., Dallas, Texas.
Seeley, W. J., prof. and dean, Dept. of E.E., Duke University, Durham, N. C.

7 to grade of Fellow

To Grade of Member

Askey, R. O., senior engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Biship, C. F., engr., Philadelphia Elec. Co., Philadelphia, Pa.
Bradley, H. L., president, Allen-Bradley Co., Milwaukee, Wis.
Burton, G. D., associate elec. engr., Navy Dept., Bureau of Ordnance, Washington, D. C.
Deederly, J. E., transmission and protection engr., Michigan Bell Tel. Co., Grand Rapids, Mich.
Eschholz, O. H., mgr., Patent Dept., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Fountain, L. L., elec. engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Francis, J. S., elec. distribution engr., Consumers Power Co., Jackson, Mich.
Freeman, Stephen, engr., Consumers Power Co., Jackson, Mich.
Graybill, H. W., design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Hill, C. G., partner, J. G. Wray & Co., Chicago, Ill.
Hoover, D. B., elec. design engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Hornbecker, G. A., elec. supt., Chase Metal Works, Waterbury, Conn.
Hunt, O. D., engr., Sylvania Electric Products, Inc., Salem, Mass.
Josberger, F. G., supervising distribution engr., Long Island Lighting Co., Mineola, N. Y.
Kisch, J. P., standards and appliance engr., Public Service Electric & Gas Co., Maplewood, N. J.
Koiner, J. S., supt. of elec. installations, General Electric Co., Philadelphia, Pa.
Linde, L. J., engr., General Elec. Co., Philadelphia, Pa.
Lotze, A. W., Lieut. USNR, Anacostia Station, Washington, D. C.
Mallory, D. D., staff member, Mass. Inst. of Technology, Cambridge, Mass.
McIntyre, M. V., chief elec. engr., U. S. Engineer Office, Santa Fe, N. Mex.
Myers, E. H., elec. design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Nugent, H. M., elec. engr., Otis Elevator Co., New York.
Princi, M. A., asst. design engr., General Electric Co., W. Lynn, Mass.
Risler, C. B., industry engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Scheffer, S. L., relay engr., Long Island Lighting Co., Roslyn, N. Y.
Smith, J. A., mgr., Australian General Elec. Pty. Ltd., Hobart, Tasmania, Australia.
Spencer, N. C., elec. engr., Gulf States Utilities Co., Beaumont, Texas.
Sperow, L. H., engr., General Electric Co., Philadelphia, Pa.
Spitler, C. H., elec. design engr., Leland Elec. Co., Dayton, Ohio.
Staff, V. E., chief of staff, DeLeuw, Cather & Co., Chicago, Ill.
von Roeschlaub, F., design engr., General Elec. Co., Philadelphia, Pa.
Wilder, R. D., engr., Public Service Elec. & Gas Co., Trenton, N. J.
Witherspoon, H. H., service engr., M. Klein & Sons, Chicago, Ill.

34 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the national secretary before January 31, 1945, or March 31, 1945, if the applicant resides outside of the United States or Canada.

To Grade of Member

Albert, N. M. (Reelection), Pac. Gas & Elec. Co., Emeryville, Calif.
Allen, A. J., Univ. of Pitt., Pittsburgh, Pa.
Bell C. C., United Shoe Mach. Corp., Beverly, Mass.

Burtis, J. H. (Reelection), Rural Elec. Adm., St. Louis, Mo.
Candler, G. L., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Cooley, M. C., W. N. Matthews Corp., St. Louis, Mo.
Coyle, C. F., Memphis St. Ry. Co., Memphis, Tenn.
Crawford, A. E., R. F. Equipment, Ltd., Amersham, England
del Valle, A., F. A., P. R. Water Res. Auth., San Juan, P. R.
Doocy, E. B., Stone & Webster Engg. Corp., Knoxville, Tenn.
Drazen, Y., Michael Drazen & Associates, St. Louis, Mo.
Eyton, J. (Reelection), Ste. Anne Paper Co., Ltd., Beaupre, Que., Can.
Gersmann, S., Tenn. Valley Auth., Knoxville, Tenn.
Gibble, S. L., Amer. Tel. & Tel. Co., Philadelphia, Pa.
Glover, R. P., Cons. Engr., Oak Park, Ill.
Hall, F. S., Great Amer. Ind., Meriden, Conn.
Harvey, G. M., Laclede Steel Co., Alton, Ill.
Honnell, M. A., Ga. School of Tech., Atlanta, Ga.
Jenks, H. C. (Reelection), Westinghouse Elec. & Mfg. Co., Cincinnati, Ohio
Jordan, E. C., Ohio State Univ., Columbus, Ohio
Kaldor, E., Plastic & Diecasting, Ltd., Christchurch, N. Z.
Keeling, H. J., Southern Counties Gas Co. of Calif., Los Angeles, Calif.
Klein, J. E. (Reelection), Canadian Laco Lamps, Ltd., Montreal, Que., Can.
Kuhn, H. H. (Reelection), Kansas City Pr. & Lt. Co., Kansas City, Mo.
Kuhner, S. W. (Reelection), Marion-Reserve Pr. Co., Marion, Ohio
Leland, G. F., Gen. Elec. Co., Schenectady, N. Y.
McClean, H. G., Crompton Parkinson, Ltd., Chelmsford, England
Mehta, I. M., Kaycee Ind., Ltd., Shikohabad, U. P., India
Miller, E. A., Giffels & Vallet, Detroit, Mich.
Miller, S. C., Matson Navig. Co., San Francisco, Calif.
Neagle, R. J., Allis-Chalmers Mfg. Co., Hyde Park, Mass.
Neville, S., Min. of Aircraft Production, London, England
Nielsen, R. A., Westinghouse Res. Labs., East Pittsburgh, Pa.
Orrick, J. T., Kauai Elec. Co., Ltd., Kauai, T. H.
Patterson, R. J. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Purifoy, G. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Rodney, H. A., E. I. du Pont de Nemours & Co., Wilmington, Del.
Sandman, D. (Reelection), Sandman Elec. Motor Co., Boston, Mass.
Saslaw, M. R., Cons. Engr., New York, N. Y.
Scott, A., Pac. Gas & Elec. Co., San Francisco, Calif.
Scott, G. W., Jr., Armstrong Cork Co., Lancaster, Pa.
Shearer, H. F. (Reelection), Can. Line Materials, Scarboro Junction, Ont., Can.
Shimp, E. H., Pub. Serv. Elec. & Gas Co., Irvington, N. J.
Sinclair, D. B., General Radio Co., Cambridge, Mass.
Stroessler, H. M. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Swift, L., Shawinigan Water & Pr. Co., St. Roch, Que., Can.
Taverner, H. B. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Tuthill, O. W., N. J. Bell Tel. Co., Newark, N. J.
Vaughn, D. W., Thirlwell, Henderson, Marine Elec. Co., Evansville, Ind.
Walker, H. K., S. C. Elec. & Gas Co., Columbia, S. C.

50 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Allen, J. P., Gen. Elec. Co., Boston, Mass.
Britt, F. L., Corning Glass Works, Corning, N. Y.
Clark, R. G., Gen. Elec. Co., Boston, Mass.
Crane, L. E., Gen. Elec. Co., Boston, Mass.
Creamer, E. C., Hyde Windlass Company, Bath, Me.
Cushman, P. G., Gen. Elec. Co., Schenectady, N. Y.
Day, G. C., Gen. Elec. Co., West Lynn, Mass.
Finman, B., Southern New Eng. Tel. Co., New Haven, Conn.
Guyer, E. M., Corning Glass Works, Corning, N. Y.
Hansen, W., Gen. Elec. Co., Boston, Mass.
Hoaglund, R. G., Allis-Chalmers Mfg. Co., Hyde Park, Mass.
James, H. E., Gen. Elec. Co., Schenectady, N. Y.
Kennison, J. A., Fitzgibbons Boiler Co., Inc., Oswego, N. Y.
Lindquist, A. J., Jr., Asso. Spring Corp., Forestville, Conn.
Quarles, G. G., Harvard Univ., Cambridge, Mass.
Saunders, S. E., Allis-Chalmers Mfg. Co., Hyde Park, Mass.
Sothman, E. P., Jackson & Moreland, Boston, Mass.
Spring, A. L., 1st Ind. Corp., Roxbury, Mass.
Steward, J. F., Sou. New Eng. Tel. Co., New Haven, Conn.
Weis, B. E. T., Jr., Lewis Engg. Co., Naugatuck, Conn.
Westgard, J. A., 1st Ind. Corp., Boston, Mass.
Wheeler, W. R., Univ. of Rochester, Rochester, N. Y.

2. Middle Eastern

Asnin, J. I., U. S. Bur. of Ord., Washington, D. C.
Braithwaite, C. H., Jr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Cline, R. W., Westinghouse Elec. & Mfg. Co., Cleveland, Ohio
Colombo, C. C., Wright Field, Dayton, Ohio
Cortelli, J. A., Clark Cont. Co., Cleveland, Ohio
Davenport, W. H., Jr., Westinghouse Res. Labs., East Pittsburgh, Pa.
Davis, R., Lieut., U. S. Army, Washington, D. C.
Ehlers, E. M., Wright Field, Dayton, Ohio
Fennell, F. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ferguson, J. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Foulds, W. L., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Fox, K. H., Bendix Radio Corp., Red Bank, N. J.
Fulford, H. G., Beth. Steel Co., Baltimore, Md.
Gerwing, T. G., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Goodwin, W. J., Nat. Adv. Comm. for Aer., Cleveland, Ohio
Gray, J. M., Maryland Dry Dock Co., Baltimore, Md.
Hall, R. C., Delaware Pr. & Lt. Co., Wilmington, Del.
Hunt, J. H. (Reelection), Toledo Edison Co., Toledo, Ohio
Knepper, M. A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Krinic, E. M., Metropolitan Edison Co., Easton, Pa.
Leak, W. H., Cincinnati Shaper Co., Cincinnati, Ohio
Levinson, E. C., U.S.C.G. Detachment, East Pittsburgh, Pa.
MacGillivray, R. H. (Reelection), Westinghouse Elec. Int. Co., Washington, D. C.
McArtor, W. A., Amer. Tel. & Tel. Co., Philadelphia, Pa.
Neyhouse, G. A., Gen. Motors Corp., Dayton, Ohio
Nickle, F. V., Nat. Adv. Com. for Aero., Cleveland, Ohio
Ramsey, T. W., General Armature Corp., Mill Hall, Pa.
Sabo, J. H., Fiberglas Corp., Newark, Ohio
Smith, H. J., Wright Field, Dayton, Ohio
Stark, G. D., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Wentker, F. W., Radio Corp. of America, Camden, N. J.
Zimmerman, H. B., Phila. Elec. Co., Philadelphia, Pa.

3. New York City

Gordon, E. F., Phelps Dodge Copper Prod. Corp., New York, N. Y.
Holmes, W. K., Mun. Pr. Plant, Freeport, N. Y.
Jones, S. F. G., N. Y. Tel. Co., New York, N. Y.
Levinson, B., Okonite-Callender Cable Co., Inc., Paterson, N. J.
McDonnell, F. W., Jersey Cen. Pr. & Lt. Co., Asbury Park, N. J.
Osgood, R. H. (Reelection), Okonite Co., New York, N. Y.
Perez, P., Corp. de Fom. de la Prod., New York, N. Y.
Purpura, S. J., U. S. Navy, New York, N. Y.
Schultz, C. H. (Reelection), American Can Co., Jersey City, N. J.
Scutt, J. M., Ford Inst. Co., Long Island City, N. Y.
Smith, A. G., Weston Elec. Inst. Corp., Newark, N. J.
Thomassen, A. E., Ebasco Services, Inc., New York, N. Y.
White, P. V., Okonite-Callender Cable Co., Inc., Paterson, N. J.

4. Southern

Albright, A. L., Cities Serv. Ref. Corp., Lake Charles, La.
Bettis, C. E., Tenn. Eastman Corp., Knoxville, Tenn.
Bradford, J. C., Memphis Lt., Gas & Water Div., Memphis, Tenn.
Campbell, J. O., Tenn. Eastman Corp., Oak Ridge, Tenn.
Custer, C. M., Southwest Pr. Pool, Little Rock, Ark.
Henry, R. W., Tenn. Val. Auth., Knoxville, Tenn.
Lloyd, T. F., Post Engrs. Office, Barksdale Field, La.
Loscalzo, V. J., Gen. Elec. Co., Atlanta, Ga.
McKeever, C. A., Tenn. Eastman Corp., Oak Ridge, Tenn.
Rockwell, T., III, Tenn. East. Corp., Oak Ridge, Tenn.
Williamson, W. W., Tenn. Eastman Corp., Knoxville, Tenn.

5. Great Lakes

Adkins, R. M., Purdue Univ., Lafayette, Ind.
Bauer, C. A. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Bauerschmidt, G. J. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Bydal, C. B., Commonwealth Edison Co., Chicago, Ill.
Dring, M. J., South Bend Elec. Co., South Bend, Ind.
Fletcher, F. L., Cen. Ill. Elec. & Gas Co., Rockford, Ill.
Floor, E., Harza Engg. Co., Chicago, Ill.
Franzen, N. O., Commonwealth Edison Co., Chicago, Ill.
Greenwald, H. H., Pub. Serv. Co. of N. Ill., Chicago, Ill.
Kibler, R. S., Cen. Ill. Elec. & Gas Co., Rockford, Ill.
Klasner, C. M., Laclede Steel Co., Alton, Ill.
Miller, A. A., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Nelson, W. E., Pub. Serv. Co. of N. Ill., Chicago, Ill.
Neteland, C. L., Commonwealth Edison Co., Chicago, Ill.
Patterson, G. H. (Reelection), Pub. Serv. Co. of N. Ill., Maywood, Ill.
Ryan, E. A. (Reelection), Commonwealth Edison Co. Chicago, Ill.
Taylor, J. W., Diamond Chain & Mfg. Co., Indianapolis, Ind.
Trompeter, J. J., Trompeter Elec. Co., Peoria, Ill.
Ungrodt, A. L. (Reelection), Commonwealth Edison Co., Chicago Ill.
Vielmetti, C. J., Pub. Serv. Co. of N. Ill., Joliet, Ill.
Wadsworth, W. J., Harza Engg. Co., Chicago, Ill.
Westrich, C. J., Sears Roebuck & Co., Chicago, Ill.
Williams, E. W., Kyle Corp., South Milwaukee, Wis.
Zipse, A. E. (Reelection), Commonwealth Edison Co., Chicago, Ill.

6. North Central

Carman, C. C., Univ. of Colo., Boulder, Colo.
Kinnear, T. H., Pub. Serv. Co. of Colo., Denver, Colo.
Langford, J. L., U. S. Bur. of Reclamation, Denver, Colo.
Little, A. A., N. W. Bell Tel. Co., Omaha, Nebr.

7. South West

Ausman, J. G., Southwestern Pub. Serv. Co., Amarillo, Texas.
Baker, L., Dallas Pr. & Lt. Co., Dallas, Texas
Blalock, L. B., Texas Pr. & Lt. Co., Dallas, Texas
Chadwick, D. N., Dallas Pr. & Lt. Co., Dallas, Texas
Cobb, C. C., Magnolia Pet. Co., Beaumont, Texas
Debney, G. C., Magnolia Pet. Co., Beaumont, Texas
Eichner, R. M., Gen. Elec. Co., San Antonio, Texas
Fontaine, J. E., Graybar Elec. Co., Beaumont, Texas
Gager, A. F., Gulf States Util. Co., Beaumont, Texas
Heitert, D. G., Emerson Elec. Mfg. Co., St. Louis, Mo.
Hodson, H. O., Southwestern Pub. Serv. Co., Amarillo, Texas
Long, W. H., E. I. du Pont de Nemours & Co., Pryor, Okla.
Nichols, R. L., Sr., Magnolia Pet. Co., Beaumont, Texas
Osborn, E. M., Osborn Elec. & Sup. Wks., Muskogee, Okla.
Reddoch, T. E., Magnolia Pet. Co., Beaumont, Texas
Slocum, J. T., Gulf States Util. Co., Beaumont, Texas
Straughn, W. L., Sr., Straughn Radio & Elec. Serv., Beaumont, Texas
Ward, F. R., Emerson Elec. Mfg. Co., St. Louis, Mo.
Woeltge, F. W., Emerson Elec. Mfg. Co., St. Louis, Mo.

8. Pacific

Arnold, W. H., L. A. Water & Pr. Dept., Los Angeles, Calif.
Dial, W. C., U. S. Navy Yard, Mare Island, Calif.
Ford, R. O., Los Angeles Water & Pr. Dept., Los Angeles, Calif.
Gielow, W. R., Pac. Gas & Elec. Co., San Francisco, Calif.
Ingalls, H. M., Cons. Vultee Aircraft Corp., Vultee Field, Calif.
Leffmann, W. W., Allis Chal. Mfg. Co., Los Angeles, Calif.
Lewis, T. E., Western Pipe & Steel Co. of Calif., San Pedro, Calif.
McNaughton, C. C., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Miller, R. D., U. S. Naval Drydocks, San Francisco, Calif.
O'Brien, R. P. (Reelection), Calif. R.R. Com., San Francisco, Calif.
Pease, H. E., L. A. Water & Pr. Dept., Los Angeles, Calif.
Percy, F. W., Con. Vultee Aircraft Corp., Tucson, Ariz.
Reed, J. F., Southern Calif. Tel. Co., Los Angeles, Calif.
Rubright, E. C., Cons. Vultee Aircraft Co., San Diego, Calif.
Sauer, T. H., Douglas Aircraft Co., Los Angeles, Calif.
Struck, D. W., Cons. Vultee Aircraft Corp., San Diego, Calif.
Tickner, H. E., Pac. Gas & Elec. Co., San Francisco, Calif.
Tregaskis, L. M., Winton Lumber Co., Martell, Calif.
Wilson, A. P., U. S. Naval Drydocks, San Francisco, Calif.
Yarbrough, C. T., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.

9. North West

Davis, R. F., City of Tacoma, Tacoma, Wash.
Kaiser, K. H., Puget Sound Pr. & Lt. Co., Deiringer, Wash.
Kennell, D. A., Pac. Tel. & Tel. Co., Portland, Ore.
McLean, J. F., Williamette Iron & Steel Corp., Portland, Ore.
McLean, W. S., Williamette Iron & Steel Corp., Portland, Ore.
Measure, A. J., Mont. Pr. Co., Great Falls, Mont.
Morrison, E. B., Ore. Ins. Rat. Bur., Portland, Ore.
Smith, W. D., Port. Gen. Elec. Co., Portland, Ore.
Wetterborg, H. A., Port. Gen. Elec. Co., Portland, Ore.
Whiteley, T. B., U. S. Navy Yard, Bremerton, Wash.

10. Canada

Bainbridge, A. S., Porritts & Spencer Co., Ltd., Hamilton, Ont., Can.
Bowen, E. K., Can. Gen. Elec. Co. Ltd., Toronto, Ont., Can.
Raymond, J. E., Can. Westinghouse Co., Ltd., Hamilton, Ont., Can.
Shirley, Mrs. Q. H., Guthrie Lab. Mach. Co., Ltd., Windsor, Ont., Can.
Vanderleck, J. M., Nat. Res. Council, Ottawa, Ont., Can.
Williamson, W. A., Can. Gen. Elec. Co., Ltd., Toronto, Ont., Can.

Elsewhere

Castorina, D., Siam di Tella, Ltda., Buenos Aires, Arg., S. A.
DiLuciano, V. F. A., Siam di Tella, Ltda., Buenos Aires, Arg., S. A.
Giuliani, J. C., Siam di Tella, Ltda., Buenos Aires, Arg., S. A.
Sarwal, S. S. D. C., C. A. V., Ltd., London, England
Singh, B., Delhi-Polytechnic, Delhi, India
Vucetich S., D., Cia. Chil. de Elec., Ltda., Santiago, Chile, S. A.

Total to grade of Associate

United States and Canada, 161

Elsewhere, 6

OF CURRENT INTEREST

ASA Announces Plan to Widen Scope of Activities

Because of the growing importance of standards for consumer goods, removal of the present restrictions which limit the work of the American Standards Association to the engineering field was authorized by the ASA board of directors at its annual meeting held in New York, N. Y., December 8, 1944. Such increased scope will necessitate reorganization of the ASA so that it can handle any standard or standardization project which deserves national recognition, whether in the field of engineering, accounting, business practice, or consumer goods.

Officers for 1945, announced at the meeting, are:

Henry B. Bryans, executive vice-president and director, Philadelphia Electric Company, re-elected president; George S. Case, chairman of the board, Lamson and Sessions Company, re-elected vice-president; H. S. Osborne, American Telephone and Telegraph Company, re-elected chairman, Standards Council, which is in charge of all ASA technical work; E. C. Crittenden, National Bureau of Standards, re-elected vice-chairman, Standards Council.

Speakers at the meeting included Rear Admiral E. L. Cochrane, chief, Bureau of Ships, United States Navy, who discussed the meaning of standardization to the Navy; Henry B. Bryans, executive vice-president of the Philadelphia Electric Company and President of the ASA; and H. S. Osborne (F '21) chairman of the Standards Council, who reported on the ASA's technical work for the year.

The accomplishments of the ASA in the past year, as in 1943, were concerned mainly with the war effort. More than 50 special war jobs were completed including 21 radio standards, 25 war standards in the photographic field, and special war specifications for occupational clothing which have now reached 21 in number. An interesting footnote to the 1943 meeting, at which participation in the organization of a United Nations Standards Body was authorized, was provided by receipt of a communication from the national standardizing body of France re-establishing relations with the United States and asking to be brought up to date on the work of the past few years.

During 1944 the ASA approved 157 standards, the highest number on record. Of the 66 standards handled under the emergency procedure established for war standards, the largest number, 27, related to the safety of workers. Most of these were concerned with protective clothing and shoes for workers. Under the regular procedure of the ASA, standards were developed to cover specifications and tests of a wide range of materials, standardizations of films and photographic processes, various safety measures, and a guide to municipal officials in the preparation of administrative sections of building codes.

Although, during the war period, the ASA has directed its work toward industrial standards of immediate use, a large postwar increase in the volume of standards for consumer goods is anticipated and the basic planning for the future of the ASA is being made with that end in mind. As an indication of the increased importance of standardization problems in the United States, a conference is being called at the request and in the name of the Secretary of Commerce of the United States, by the visiting committee of the National Bureau of Standards, for the purpose of recommending action that will meet a large volume of criticisms received by the Department of Commerce, leveled at alleged inadequacy of function and lack of coverage by the existing organizations in the standardization field. To cope with this contingency, the ASA is developing a broad program which, it believes, will prove acceptable to industry, to consumers, and to the Government.

WAR PROGRAM • •

Troopships Provided With Package Power Plant

A "packaged" power plant, consisting of a 3,500-horsepower turbine, generator, and condenser, is being manufactured by the Westinghouse Electric and Manufacturing Company for installation on troopships and cargo vessels. This "package" is complete, even to the lubricating oil system, pumps, and piping, and need only be connected.

The new ships in which these plants are used are twin screw with each shaft turned by a 3,300-horsepower slow-speed 80-cycle synchronous motor. Auxiliary power is provided by separate generating units. The excitation for the generators is controlled by a rotating regulator of the Rototrol type which permits smaller normal excitation power but provides a rapid boosting of excitation in emergencies. The system provides an automatic control of stability.

Distinguished Service Award for Moore School. In recognition of the value of its research and development work in furthering the war effort, the Moore School of Electrical Engineering of the University of Pennsylvania has been granted the Army Ordnance Department's Distinguished Service Award.

Rural Electrification Increased. With the addition of more than 400 new farm customers during the first nine months of 1944, the Public Service Company of Northern Illinois has pushed the total number of farm and rural units served with electricity past the 24,800 mark and has lengthened its rural power lines by 50 miles. These new farm customers are being added wherever applicants can justify their wartime need for electricity under War Production Board regulations. As evidence of the greater use of electricity in the production of foods for the war, the company cites an average increase for the year of 181 kilowatt-hours per farm customer. Among the electric work-saving farm equipment in use in northern Illinois are chick and pig brooders, milking machines, water pumps, and grain elevators.

INDUSTRY • • • • •

New System of Modulation Presented at IRE Meeting

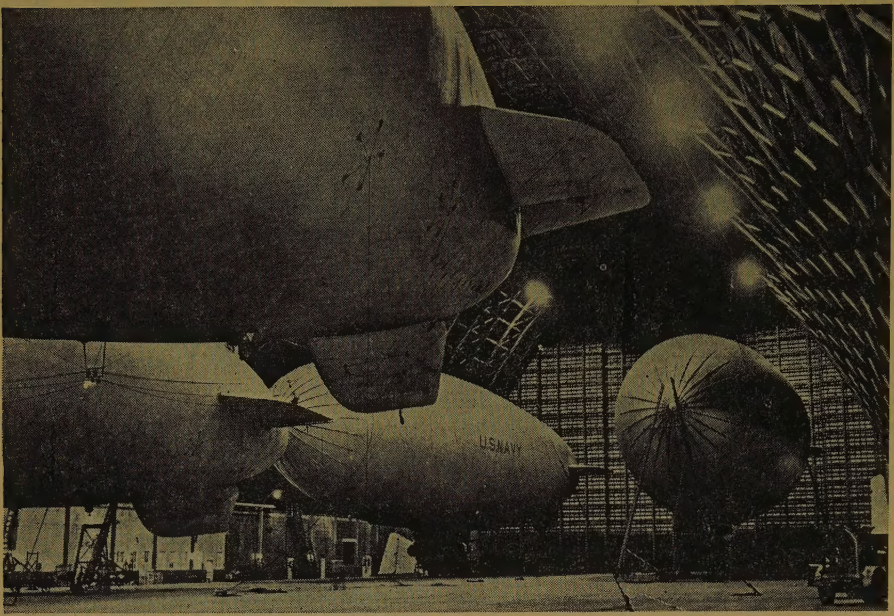
Development of a system of pulse time modulation, applicable to wire and radio transmission, including broadcasting and television sound channels, was disclosed at a meeting of the Institute of Radio Engineers in a paper by E. Labin and E. M. Deloraine. The authors are connected with the Federal Telephone and Radio Laboratories, an associate of the International Telephone and Telegraph Corporation.

Pulse time modulation consists essentially in transmitting intelligence by pulses of constant amplitude and duration. The instantaneous amplitude of the voice is translated into a variation of time intervals of successive pulses, the rate of this variation corresponding to the instantaneous frequency of the signal. Its main advantages include simplification derived from the use of more rugged repeaters, capable of operating on trigger action, thereby materially reducing the usual requirements for stability, distortion, and noise. Further, distortions introduced in the different repeaters are not cumulative.

Research and development work was started in 1937 on the basis that modern transmission technique at high frequencies was confronted with the fact that much wider bandwidths per channel are available than strictly required by the elements of most signals to be transmitted. Compared with amplitude modulation and frequency modulation, pulse time modulation appears particularly promising for application to multichannel, coaxial cable, telephone, telegraph, and facsimile transmission systems, also to point-to-point radio and ultrahigh frequency broadcasting and to television sound channels.

Gas Turbine Explained in Movie. The story of the development and operation of the gas turbine, new source of prime power, is told in a movie entitled "Tornado in a Box" which has just been released. The film, which is 16 mm for use on sound projectors only, may be either borrowed without charge or purchased by interested engineering or industrial groups from the Allis-Chalmers Manufacturing Company, Milwaukee 1, Wis. "Tornado in a Box" contains no advertising and is the third in a series, preceding titles being "The Magic of Steam" and "The Surface Condenser."

Mercury Lamp Improves Hangar Lighting



A new three-kilowatt mercury lamp, seven times larger than any air-cooled mercury lamp heretofore available, which answers the lighting requirements of the vast working spaces of blimp hangars, airplane factories, and steel mills, is being manufactured by the Westinghouse Electric and Manufacturing Company. In successfully meeting the extreme mounting-height conditions of 130 feet in this blimp hangar, the new lamp casts relatively little shadow. The five-foot-long tubular lamp delivers a total of 120,000 lumens in comparison with the 33,000 lumens of a 1,500-watt incandescent lamp. Used for both direct and indirect lighting, the lamp is especially suited to direct lighting for high-bay areas where its powerful glare is ordinarily beyond the line of vision

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SAFETY

These items are compiled by the AIEE committee on safety, W. R. Smith, chairman.

This column inaugurates a service which the committee on safety anticipates will prove of value to members of the Institute whether or not they are identified in a specific way with the field of accident prevention.

No engineer can move very far in the fields of design, construction, operation, or maintenance without developing a realization of the extent to which his plans and actions are influenced by safety considerations. Certainly, any design that is not safe to use and maintain is not representative of best engineering in the thinking of today, no matter how efficient or usable the particular device or machine may be. In like manner, construction, operation, and maintenance procedures and practices should be abreast of the times and in keeping with the trends in such matters which have been dictated by both experience and the greatly intensified effort which is being made to foresee hazards to personnel and either eliminate them or prepare in advance to meet them. Human life is too great a price to pay for failure to understand and apply the fundamental principles which underly the safe use of electric energy in all of its phases from generation through transmission and distribution to consumption at the command of the users in homes, industries, and commercial establishments.

It will be the purpose of this column to provide means for bringing to the attention of members of the Institute items of news and information in the field of electrical safety.

ELECTRIC SHOCK

Electrical engineers in all phases of their professional life and in their outside contacts with groups and individuals can render a real service to the cause of safe use of electricity if they will avail themselves of opportunities to disseminate knowledge and a better understanding of the conditions under which even low voltages can be dangerous. This does not mean the giving of prepared talks—although such talks to parent–teachers associations and many other groups can be of great value—but rather seeing to it that obvious carelessness which arises out of ignorance does not go unnoticed and uncorrected. The low-voltage fatalities that occur usually are the consequence of lowered skin resistance from moisture or because of large contact area. The fact that such victims have received "mild" shocks on one or more occasions when conditions were favorable often serves but to "condition" them for the subsequent serious happening by giving a false sense of security. The price that later is paid for a moment of carelessness or overconfidence is too great.

FATALITIES IN ELECTRIC LIGHT AND POWER INDUSTRY

A recent report by D. C. Stewart, of the Niagara Hudson Power Corporation to the accident-prevention committee of the Edison Electric Institute on the causes of fatalities in the electric light and power industry in 1943 is called to the attention of all engineers in that field and that of general industry. This report shows that electric shocks and burns continue to be the power industry's number-one problem, despite the fact that the way to prevention is known to be through the proper use of rubber protective equipment and observance of safe working practices and procedures. This report appears in the October 1944 issue of Edison Electric Institute *Bulletin.*

RESUSCITATION TECHNIQUES

Pole-Top Resuscitation. Engineers in the electric light and power industry and those with railroads or large industrial organizations employing linemen who are not already informed will find pamphlet *K*8 of the Edison Electric Institute helpful to an understanding of the purpose and the techniques of this method. This contribution to the field of artificial respiration, which was made by the Duquesne Light Company some years ago, shows the way to employ, with the desired promptness, the principles of Schafer's prone-pressure method to the special needs of the lineman on the pole.

Eve's Rocking Method. While not new in principle, this procedure is particularly suited to the need for prolonged artificial respiration, especially that necessitated by long immersion in cold water. The method is described in an article by Frank C. Eve of Hull, England, who proposed it for use by the British Navy, in the *Journal* of the American Medical Association of April 1, 1944. It is discussed in a recent paper by Cecil K. Drinker, professor of physiology in the Harvard School of Public Health, which appeared in the July 1944 issue of the Oklahoma State *Medical Journal.* The subject of the paper is "The Restoration of Breathing in Emergencies and the Maintenance of Respiration in Nonbreathing Patients." It is important to note that, whereas the pole-top method is truly a first-aid method, the Eve method is more suited to the continuance of artificial respiration for long periods. The prone-pressure method should be employed at once even though a suitable rocking mechanism is available, and then, if by the time the rocking device arrives there is no evidence of recovery, the choice can be made between continuing with prone pressure or placing the victim on the rocking board. The fundamental underlying artificial respiration is that it must be started at once with the least delay.

BIBLIOGRAPHY ON ELECTRICAL SAFETY

The committee on safety is planning a revision of this pamphlet which was first issued in July 1942. The committee would welcome comments on the value of this publication and also suggestions concerning important references that should be included. Copies can be obtained from Institute headquarters, and comments and suggestions should be sent to the committee's secretary, A. B. Campbell, 2 Rector Street, New York 6, New York.

INFORMATION

The chairman of the committee on safety is desirous of having the committee serve the members in any respects that may be consistent with its purposes and scope. Obviously, answers to questions having to do

with local conditions that would have to be investigated, in general, cannot be attempted, but appropriate inquiries may be addressed to the secretary, and effort will be made to supply the desired information.

LITERATURE

There are in the files of the chairman or other members of the committee copies of the literature that are referred to in this column, or the sources of such and other literature that may be of interest are known. Information will be supplied when requested, and in some instances copies may be available for reading and return. Address the secretary.

MEETING OF COMMITTEE

The committee on safety expects to hold a meeting January 23 at 2:00 p. m. during the 1945 winter technical meeting of the Institute. Institute members who are in attendance and are interested are invited.

OTHER SOCIETIES

IES Appoints Technical Secretary

The appointment of Cazamer L. Crouch as full-time technical secretary of the Illuminating Engineering Society has been announced. This assignment constitutes one phase of IES plans for the expansion of its technical and research activities.

As technical secretary Mr. Crouch will act as consultant to the technical committees and to the council of IES. His major assignment will be the compilation, writing, and publication of the IES Illumination Design Handbook.

Mr. Crouch will also be available for assistance in the society's newly established research program, under the direction of the board of research trustees. Newly elected officers of this board are:

P. H. Daggett, dean of the college of engineering, Rutgers University, New Brunswick, N. J. chairman.

A. H. Nicoll, president, the Graybar Electric Company, New York, N. Y. treasurer.

A. Dexter Hinckley, secretary.

The board, a completely autonomous group, sponsored though not controlled by IES, will act as trustees of the IES research fund. Individual research projects are expected to be carried out with the co-operation of the research laboratories of leading universities and other institutions.

ASRE Elects 1945 Officers

J. F. Stone, manager of the refrigeration division, Johns-Manville Corporation, New York, N. Y., has been elected president of The American Society of Refrigerating Engineers according to a recent announcement.

Other officers elected are: Charles S. Leopold, consulting engineer, Philadelphia, Pa., and Roland H. Money, chief refrigeration engineer, the Crosley Corporation, Cincinnati, Ohio, as vice-presidents; John G. Bergdoll, Jr., chief engineer, York Corporation, York, Pa., as treasurer; and, as directors for three-year terms, B. H. Jennings, professor of mechanical engineering, Northwestern University, Evanston, Ill.; Charles S. Neeson, chief engineer of the cooling division, Airtemp division, Chrysler Corporation, Dayton, Ohio; John S. Forbes, president, Superior Valve and Fittings Company, Pittsburgh, Pa.; Warren W. Farr, president and treasurer, Refrigeration Maintenance Corporation, Cleveland, Ohio; and C. Hill Garrison, C. H. Garrison Company, Kansas City, Mo.

Future Meetings of Other Societies

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 18–22, 1945, New York, N. Y.

American Society for Testing Materials. Spring meeting, February 28, 1945, Pittsburgh, Pa.

American Society of Civil Engineers. Annual meeting, January 17–19, 1945, New York, N. Y.

Canadian Electrical Association. Annual winter conference, January 18–19, 1945, Montreal, Canada.

Edison Electric Institute. Transmission and distribution committee, February 15–16, 1945, Pittsburgh, Pa.; electrical equipment committee, February 14–15, 1945, Cincinnati, Ohio; accident prevention committee, February 15–16, 1945, Cleveland, Ohio.

Institute of Radio Engineers. Winter technical meeting, January 24–27, 1945, New York, N. Y.

Institute of the Aeronautical Sciences. 13th annual meeting, April 1945, Detroit, Mich.

EDUCATION

Engineering Scholarships Offered. Ten scholarships, now valued at $1,850 each, will be awarded for an engineering education at the Carnegie Institute of Technology, Pittsburgh, Pa., according to an announcement of the Westinghouse Electric and Manufacturing Company, sponsor of the 1945 George Westinghouse Scholarship contest. The contest is open to all senior high-school boys in the United States who present a good high-school scholastic record, are able to meet the Carnegie Institute of Technology's entrance requirements, and who did not compete in the 1944 competition. Applications will be accepted until February 1, 1945, and the tests will be administered by the college entrance examination board on April 7, 1945.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Armature-Winding Resistance

To the Editor:

The a-c resistance of an armature winding is greater than the d-c resistance on account of the eddy currents produced in the conductors by the slot-leakage flux. The extra loss caused by these eddy currents can be computed with excellent precision by means of hyperbolic functions. The extra loss factor depends upon the frequency, the geometrical arrangement of the conductors, and their resistivity. If the resistivity is increased, the extra loss factor is reduced. That is, the extra loss factor for an armature winding is less when the winding is hot than when it is cold. For a well-designed armature winding in which the eddy-current loss is not excessive, the extra loss factor can be computed from the first terms of the series expansions of the hyperbolic functions. This is a common procedure. For example see reference 1. The first term of the hyperbolic series varies as the inverse square of the resistivity. Since the increase in the resistance caused by the a-c equals the d-c resistance (which varies directly with the resistivity) multiplied by the extra loss factor (which varies inversely as the square of the resistivity), the increase in the resistance varies inversely as the first power of the resistivity. Consequently, in general:

$$R_{ac} = R_{dc} + \frac{K}{\rho}$$

where K/ρ, which equals $(R_{ac} - R_{dc})$, is due to the extra loss caused by the eddy currents. The resistivity, ρ, varies with the temperature.

$$\rho \text{ at } t_2 = \frac{234.5+t_2}{234.5+t_1} \times (\rho \text{ at } t_1)$$

Let the subscripts 1 and 2 indicate resistances at temperatures t_1 and t_2. The a-c resistance at temperature t_2 is:

$$R_{ac2} = \frac{234.5+t_2}{234.5+t_1} R_{dc1} + \frac{234.5+t_1}{234.5+t_2} (R_{ac1} - R_{dc1})$$

Thus the a-c resistance of an armature winding at a temperature t_2 can be computed easily from the a-c resistance and the d-c resistance of the winding at a temperature t_1. This correction for the effect of temperature is applied to the transformer in reference 2. The correction can be used in many situations where the eddy-current loss is not excessive.

REFERENCES

1. Reduction of Armature Copper Losses, **Ivan H. Summers.** AIEE *Transactions*, volume 46, 1927, February section, pages 101–08.

2. Magnetic Circuits and Transformers (book). **Electrical-engineering staff,** Massachusetts Institute of Technology, Cambridge, Mass.

WALDO V. LYON (F '33)

(Professor of electrical machinery, Massachusetts Institute of Technology, Cambridge, Mass).

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Basic Structures. By F. R. Shanley. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, London, England, 1944. 392 pages, illustrated, 8¼ by 5½ inches, cloth, $4.50. (ESL.)

The opening chapters describe simple kinds of forces and force systems and develop the methods of transmitting these forces through space. From that point on the arrangement has been dictated by the actual development and analysis of the structure as a means of force transmission with particular emphasis on the physical action involved. The mathematical treatment has been kept as simple as possible. Special application is made to the design and analysis of aircraft structures.

Chemical Industry. By J. Perry. Longmans, Green and Company, New York, N. Y., and Toronto, Ont., Canada, 1944. 128 pages, illustrated, 8½ by 6 inches, cloth, $1.75. (ESL.)

Beginning with a brief survey of the history of chemistry in ancient times, this small book continues with the growth of the chemical industry in the United States from early times to the present. Important products and processes are discussed in a simple concise manner, including a chapter on synthetic products. The volume is one of a series covering the important industries of this country.

Direct-Current Circuits (Rochester Technical Series). By E. M. Morecock. Harper and Brothers, New York, N. Y., and London, England, 1944. 387 pages, illustrated, 9½ by 6 inches, cloth, $3.25. (ESL.)

Designed as a basic course for elementary study, this text provides selected laboratory experiments and a variety of problems for review purposes. A working knowledge of algebra and logarithms but not calculus is required. The separate chapters deal with elementary electric circuits, magnetism and electromagnetism, instruments and measurement methods, power and energy, conductors and insulation, batteries, the magnetic circuit, electromagnetic induction, capacitance, and electrostatics.

Electronics. By J. Mills. D. Van Nostrand Company, New York, N. Y., 1944. 178 pages, illustrated, 8 by 5 inches, cloth, $2.25. (ESL.)

The simple characteristics of electrons, both in nature and as used by science, are discussed in the introductory chapters. The following section describes the evolution and operation of the more important kinds of electron tubes, vacuum or gas-filled. The last section is devoted to explanation of various electronic devices for television, electron microscopy, ultrahigh-frequency apparatus, and the cyclotron. The book is designed for the "intelligent layman."

Infrared Spectroscopy. By R. B. Barnes, R. C. Gore, U. Liddel, and V. Z. Williams. Reinhold Publishing Corporation, New York, N. Y., 1944. 236 pages, illustrated, 9¼ by 6 inches, fabrikoid, $2.25. (ESL.)

This work is a "partial answer to the increasing demand for information concerning the industrial applications of infrared spectroscopy." The theory of infrared absorption and its relation to molecular structure are discussed to provide the background for a description of techniques useful in analysis. A "library" of 363 representative spectra of organic compounds is presented for comparison with those obtained from unknown compounds. A bibliography of over 2,500 references is given. The material, except the bibliography, was first published in *Industrial and Engineering Chemistry.*

Man's Fight to Fly. By J. P. V. Heinmuller, foreword by E. Rickenbacker. Funk and Wagnalls Company, New York, N. Y., and London, England, 1944. 366 pages, illustrated, 11 by 8 inches, fabrikoid, $6. (ESL.)

The author of this book has for many years been observer and chief timer for the National Aeronautic Association, in which capacity he has timed most of the transatlantic and round-the-world flights. He has known nearly all the prominent flyers. His book gives his personal recollections of many world-record flights, illustrated by photographs from his collection. A chronology of aviation from 1483 to 1939 points the outstanding steps in development.

Men of Science in America. By B. Jaffe. Simon and Schuster, New York, N. Y., 1944. 600 pages, illustrated, 9 by 6 inches, cloth, $3.75. (ESL.)

A broad picture of the growth of science in the United States is presented by means of a series of biographical sketches. The lives and achievements of 19 of the foremost American scientists are viewed against their historical background, with emphasis on the influence of scientific discovery upon the social structure of the country. The future of science in America is suggested briefly in the last chapter, and a full list of sources and reference material is included.

Methods of Advanced Calculus. By P. Franklin. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1944. 486 pages, illustrated, 8½ by 5¼ inches, cloth, $4.50. (ESL.)

This textbook is designed for students whose major field of interest is engineering, mathematics, or science, but it also may serve the practicing engineer or applied scientist as an introduction to the more formidable mathematical treatises. The two principal objectives of the book are: to refresh and improve the student's technique in applying elementary calculus and to present those methods of advanced calculus most needed in applied mathematics.

Military and Commercial Aircraft Hydraulics. By R. N. Greif. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1944. 113 pages, illustrated, 8¼ by 5¼ inches, cloth, $2. (ESL.)

This practical book describes in detail the basic units of hydraulic systems, beginning with elementary applications and working up to complete systems for aircraft purpos[es]. Maintenance, inspection, trouble shootin[g] and repair are covered in the later chapte[rs] and a separate chapter is devoted to [an] explanation of hydraulic plumbing detai[ls]. The book is intended both as a text and [a] reference manual for the practical mechan[ic].

Extrusion of Metals. By C. E. Pearso[n] with a foreword by R. Genders. John Wil[ey] and Sons, Inc., New York, N. Y.; Chapma[n] and Hall, London, England, 1944. 2[0?] pages, illustrated, 8¾ by 5½ inches, clot[h], $3.75. (ESL.)

We have here a concise account of e[x]trusion practice relating to different class[es] of work and materials, based on the wide[ly] scattered information available in the litera[ture] and on the author's own studie[s]. Chapters on flow phenomena in the proce[ss] and on the influence on the extrusion [of] metals of such factors as temperature and th[e] speed and extent of deformation are include[d]. Impact extrusion also is discussed.

PAMPHLETS • • • •

The following recently issued pamphlets may b[e] of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuer.

An Engineering Interpretation of th[e] Economic and Financial Aspects of Ameri[can] Industry, Volume VI, the Electroni[c] Industry. George S. Armstrong and Com[pany], Inc., 52 Wall Street, New York, N. Y. Limited number available upon request. 7[?] pages.

Accident Rates in the Machinery and Electrical Equipment Industry, 1943. National Safety Council, 20 North Wacke[r] Drive, Chicago 6, Ill., 11 pages.

Flexible Shaft Handbook. Second edition. S. S. White, 10 East 40th Street, New Yor[k] 16, N. Y., 256 pages.

Loans To Small Business. Smaller Wa[r] Plants Corporation, Washington, D. C., 1[?] pages.

Lighting Specific for Tobacco Stripping, Unloading, and Auction Warehouse Space, 5 pages. **Lighting for Shipyards,** 12 pages. **Lighting for the Synthetic Rubber Industry,** 10 pages. **Lighting Specific fo[r] Railroads,** 22 pages. **Protective Lighting,** 21 pages. **Lighting for the Hospital o[f] Today,** 24 pages. **Lighting for the Oi[l] Refining Industry,** 26 pages. Holophan[e] Company, 342 Madison Avenue, New York, N. Y., no charge.

Postwar Surveys of the Packaging Possibilities of the Electrical Radar and Radi[o] Equipment Industry. National Paper Bo[x] Manufacturers Association, Philadelphia, Pa., 5 pages.

Corrosion. The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y., 54 pages.

Unemployment Insurance in the Secon[d] Year of War. State of New York Department of Labor, Albany, N. Y., 28 pages.